

**SHRP 2 C16 The Effect of Smart Growth Policies  
on Travel Demand**

**SMARTGAP USER'S GUIDE**

Prepared for  
The Strategic Highway Research Program 2  
Transportation Research Board  
of  
The National Academies

**TRANSPORTATION RESEARCH BOARD  
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## **CHAPTER 1. INTRODUCTION TO THE SHRP 2 C16 PROJECT**

### **Project Overview**

This document is the user's guide for the Smart Growth Area Planning (SmartGAP) software, which is a tool for evaluating the impact of various smart growth policies. The tool was developed as part of the SHRP 2 C16 project, which provided tools, methods, and resources for transportation planning agencies in the U.S. to evaluate the effects of smart growth policies on travel demand. The project built on existing work in this field, while recognizing that this is a relatively new arena of study in transportation planning. The research team's development of tools and on-line resources relied on research, performance metrics and application tools already in use. The tools and resources were reviewed by the project's Technical Expert Task Group and by select Metropolitan Planning Organizations (MPOs) and state Departments of Transportation (DOTs) who engaged in pilot studies of SmartGAP.

### **Project Objectives**

The overall goal of project SHRP 2 C16 was to provide transportation planning agencies with improved tools and methods for more accurately and comprehensively integrating transportation investment decision-making with land development and growth management. To achieve this objective, there were several objectives:

- Understanding the critical decision points in the transportation planning process for highway capacity and assessing whether, how and to what extent smart growth approaches to land use policies and planning may affect demand for such capacity.
- Reporting on existing research to understand the dynamics and inter-relationships of smart growth strategies with the performance of a transportation investment.
- Building on existing applications to identify the range of features and capabilities these tools and methods need to represent, including the performance metrics needed to assess smart growth alternatives.
- Facilitating improved communication, interaction and partnerships between decision-makers and planners in both the transportation and land use arenas.

To ensure this project results in products that are “ready to use” and have enduring value, technical guidance, tools and resources will be integrated into the four phases of decision-making addressed by the evolving web-based *TCAPP Transportation Capacity Decision Guide*.

### **Organization of this User's Guide**

This user's guide is organized into the following sections:

- SmartGAP introduction and model design (more detail on the technical aspects of the model such as discussion of model specifications can be found in the SHRP 2 C16 final report)
- Installation instructions: installing R, about R, and installing SmartGAP

- Running SmartGAP: about the user interface, creating projects and scenarios, running the model, viewing and export output, and creating charts to compare results across scenarios
- Developing input data
- Evaluating outputs: performance metrics
- SmartGAP implementation examples: examples from the pilot testing of SmartGAP to provide guidance on how an agency could use SmartGAP

## CHAPTER 2. DESIGN OF SMARTGAP

### Objectives of the Software Tool

SmartGAP is a tool for evaluating the impact of various smart growth policies. SmartGAP is designed to be a high level evaluation at a regional scale that can bridge the distance between evaluating smart growth policies during a regional visioning process and evaluating smart growth policies at a project or alternative level in a regional transportation plan. SmartGAP evaluates policy scenarios to identify the most promising policies that could be further tested using a more detailed project-level tool. Currently, SmartGAP can provide information on the following changes in the regional system:

- **Built Environment** – changes to the urban form (proportion of population and employment living in mixed use areas, transit oriented developments, or rural/greenfield areas)
- **Travel Demand** – changes in population demographics (age structure), changes in personal income, changes in firms by size or industry, relative amounts of development occurring in urban core, close in communities, suburban or rural areas, urban core, auto and light truck proportions by year, and induced demand
- **Transportation Supply** – amounts of regional transit service, amounts of freeway and arterial capacity
- **Policies** – pricing (vehicle miles traveled charges or parking pricing programs), ITS strategies for freeways and arterials, demand management (vanpool, telecommuting, ridesharing, and transit pass programs)

SmartGAP is designed to evaluate regions, which can be a multi-county metropolitan region. It distinguishes between population and employment living/working in the urban core, close in communities, suburban and rural/greenfield areas based on densities, diversity in land uses, street design or intersection densities, job accessibility by auto, distances to transit stops, and connectivity of the street system.

The intended audience for SmartGAP) is regional decision-makers and land use and transportation planners involved in the development and evaluation of transportation and land use policies and who need to conduct scenario planning to evaluate smart growth policies and determine their impact on travel demand. SmartGAP was designed to address as many of the limitations identified in the research as possible and to provide a tool that filled a gap in the set of available tools. The relationships in the SmartGAP tool were based upon the background research conducted for the SHRP 2 C16 project. SmartGAP is designed to allow the evaluation of a wide range of policies and combination of policies in a consistent framework quickly and easily so that promising smart growth strategies can be identified and pursued in the land use and transportation planning processes. SmartGAP is intended to precede and supplement more sophisticated modeling efforts, which can be used to evaluate specific smart growth projects. It is designed to be accessible to land use and transportation planners with no modeling experience.

## Model Structure

SmartGAP is a disaggregate policy model that predicts travel demand impacts at an individual household level. Figure 2-1 presents the modeling system with inputs, model components, and feedback loops.

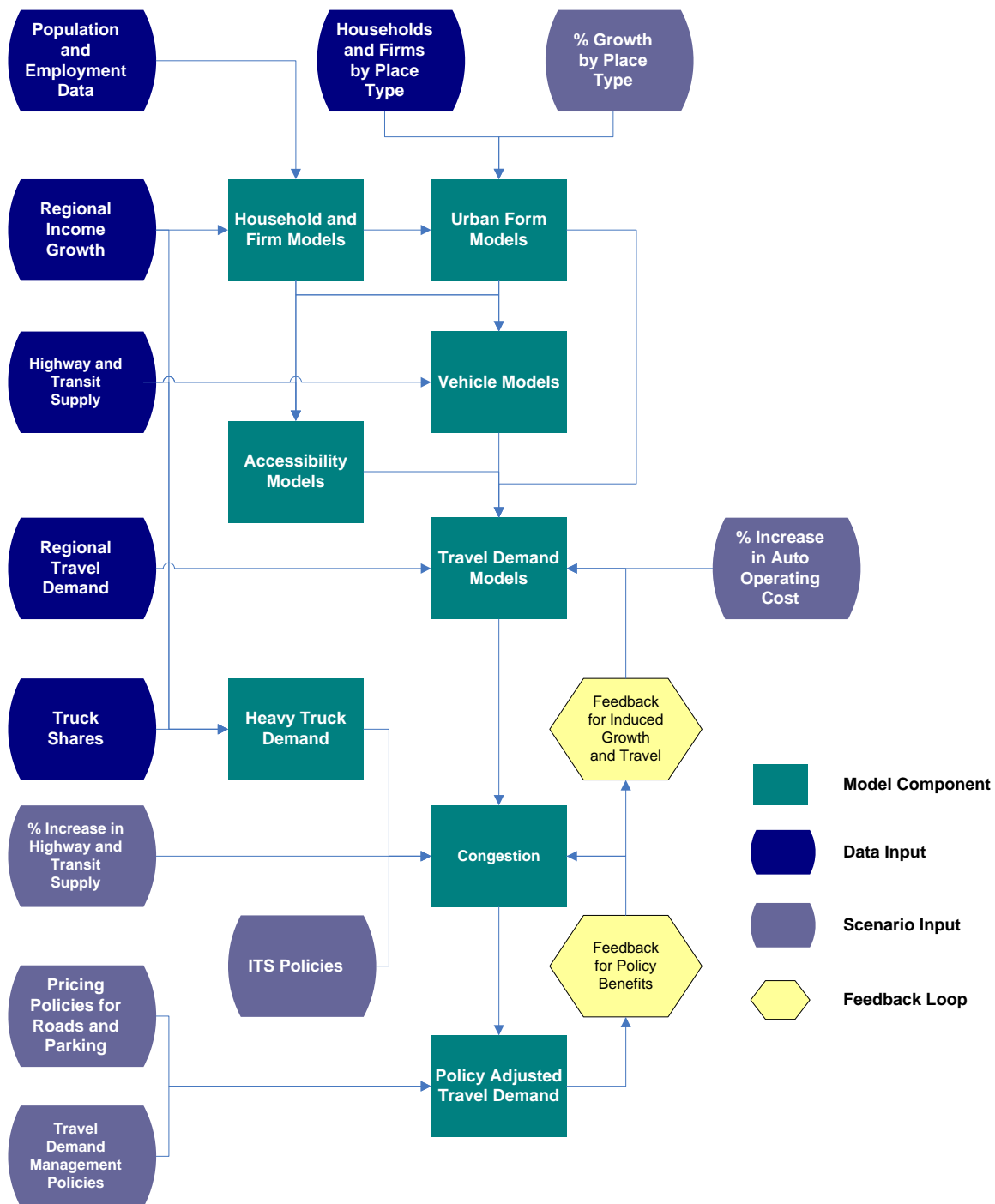


Figure 2-1: Overview of Modeling Process

SmartGAP does not provide specific spatial results beyond the built environment categories at the regional level, but does capture individual household and firm characteristics and the interactions between policies. The disaggregate nature of the model captures impacts that may be occurring for small portions of the population (say 0-vehicle households) where aggregate models have a more difficult time capturing these impacts.

The following is an explanation of major steps in the model execution in Figure 2-1.

#### *Household and Firm Model*

- **Create Synthetic Households** - A set of households is created for each forecast year that represents the likely household composition for the region, given the county-level forecast of persons by age. Each household is described in terms of the number of persons in each of six age categories residing in the household. A total household income is assigned to each household, given the ages of persons in the household and the average per capita income of the region where the household resides.
- **Create Synthetic Firms** - A set of firms is created for each forecast year that represents the likely firm composition for the region, given the County Business Pattern data of firms by size and industry. Each firm is described in terms of the number of employees and its industry.

#### *Urban Form Model*

- **Calculate Place Types for Households and Firms** - Population and employment location characteristics are important variables in the vehicle ownership, travel demand, and accessibility models. There are 4 place types (urban core, close in community, suburban, and rural) and 5 location categories (residential, commercial, mixed-use, transit oriented development, and Greenfield). Models for households were developed to estimate location characteristics using National Household Travel Survey data. Firms are currently allocated randomly to fit the employment allocation inputs since there are no national datasets from which to draw these relationships.

#### *Accessibility Model*

- **Calculate Freeway, Arterial, and Public Transit Supply Levels** - The number of lane-miles of freeways and arterials is computed for each region based on the change in inventories for a particular scenario. For public transit, the inputs specify the change in transit revenue miles relative to the base. Inputs for each area also specify the revenue mile split between electrified rail and buses.

#### *Vehicle Model*

- **Calculate Vehicle Ownership** - Each household is assigned the number of vehicles it is likely to own based on the number of persons of driving age in the household, whether only elderly persons live in the household, the income of the household, the population density where the household lives, the freeway supply, the transit supply, and whether the household is located in an urban mixed-use area.

### *Travel Demand Model*

- Calculate Travel Demand - The average daily vehicle miles traveled, auto and transit trips for each household is modeled based on household information determined in previous steps for the base conditions. The model is sensitive to household income, population density of the neighborhood where the household resides, number of household vehicles, whether the household owns no vehicles, the levels of public transportation and freeway supplies in the region, the driving age population in the household, the presence of persons over age 65, and whether the neighborhood is characterized by mixed-use development.
- Calculate Truck and Bus VMT - Regional truck VMT is calculated based on changes in the regional household income. As a default, a one-to-one relationship between regional income growth and truck VMT growth is assumed. In other words, a doubling of total regional income would result in a doubling of truck VMT. Bus VMT is calculated from bus revenue miles that are factored up to total vehicle miles to account for miles driven in non-revenue service.

### *Congestion Model*

- Calculate the amount of congestion – Auto, and light truck VMT, truck VMT and bus VMT in are allocated to freeways, arterials, and other roadways. Truck and bus VMT are allocated based on mode-specific data, and auto and light truck VMT are allocated based on a combination of factors and a model that is sensitive to the relative supplies of freeway and arterial lane miles. System-wide ratios of VMT to lane miles for freeways and arterials are used to allocate VMT to congestion levels using congestion levels defined by the Texas Transportation Institute for the Urban Mobility Report. Each freeway and arterial congestion level is associated with an average trip speed for conditions that do and do not include ITS treatment for incident management on the roadway. Overall average speeds by congestion level are calculated based on input assumptions about the degree of incident management. Speed vs. fuel efficiency relationships for light vehicles, trucks, and buses are used to adjust the fleet fuel efficiency averages computed for the region.

Following initial calculations for baseline conditions, the model has feedback loops, which allow for changes in travel demand and other impacts based on induced travel demand and for changes in policies for a given scenario. Congestion is recalculated following these adjustments to demand.

### *Induced Demand Model*

- Calculate Induced Travel Demand – Induced demand is calculated for changes in roadway supply in the near term as a function of speed, based on potential mode and route shifts to produce changes in vehicle miles traveled and in the longer term to include changes in vehicle ownership, still as a function of speed. This model does not include induced demand as a result of changes in growth that may occur as part of a smart growth scenario because the evidence is limited empirical evidence.

### *Policy Adjusted Travel Demand*

- Calculate Scenario Travel Demand – The average daily vehicle miles traveled for each household can be adjusted based on changes in growth patterns by place type, changes in auto operating cost, changes in road lane miles or transit revenue miles for any scenario. There are also a series of policy assumptions that can contribute to changes in vehicle miles traveled: pricing such as vehicle miles traveled charges or parking pricing, ITS strategies for freeways and arterials, and vanpool, telecommuting, ridesharing, and transit pass programs. All of these will contribute to shifts in travel demand for a given scenario.

### *Performance Metrics*

- Calculate Performance Metrics – The other impacts that are produced for a given scenario include environment and energy impacts (GHG emissions and fuel consumption), financial and economic impacts (highway and transit infrastructure costs, transit operating costs, and traveler costs), regional accessibility, and community impacts (livability and public health indicators).

## CHAPTER 3. INSTALLATION INSTRUCTIONS

### Introduction

The installation of SmartGAP is a two-step process.

1. Install R
2. Install SmartGAP

These two steps are described in this section of the user's guide.

### Installing R

#### *What is R?*

SmartGAP is implemented in R. R is a freely available language and environment for statistical computing and graphics which provides a wide variety of statistical and graphical techniques: linear and nonlinear modeling, statistical tests, time series analysis, classification, clustering, etc. R is available from the Comprehensive R Archive Network (CRAN), a network of ftp and web servers around the world that store identical up-to-date versions of code and documentation for R.

#### *Downloading R*

Download the latest version of R from CRAN: <http://cran.r-project.org/>. R is available for Linux, Mac OS X, and Windows; the current version (as of May 2012) is R-2.15.0.

#### *Installing R*

Installation instructions are at [http://cran.r-project.org/doc/FAQ/R-FAQ.html#How-can-R-be-installed\\_003f](http://cran.r-project.org/doc/FAQ/R-FAQ.html#How-can-R-be-installed_003f). There are two platform specific FAQ sites that contain detailed installation instructions for Windows (<http://cran.r-project.org/bin/windows/base/rw-FAQ.html>) and Mac OS X (<http://cran.r-project.org/bin/macosx/RMacOSX-FAQ.html>).

#### *R Resources*

There are many resources for helping newer R users become more familiar with using R for data analysis and modeling. Here are some places to get started:

- Manual and introduction to R: <http://cran.r-project.org/manuals.html>
- Journal: *The R Journal* (<http://journal.r-project.org/>) is the refereed journal of the R project for statistical computing. It features short to medium length articles covering topics that might be of interest to users or developers of R.
- Wiki: <http://rwiki.sciviews.org/doku.php>
- Online resource list: <http://rwiki.sciviews.org/doku.php?id=links:links>

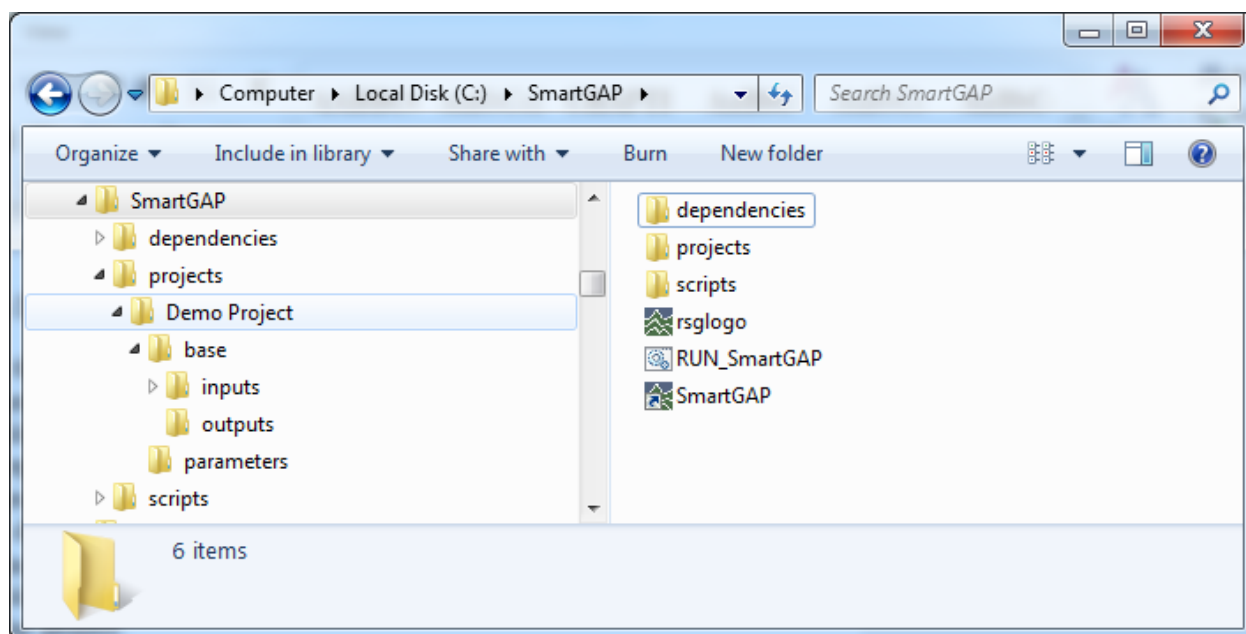


- Books: <http://www.r-project.org/doc/bib/R-books.html>
- R function reference card: <http://cran.r-project.org/doc/contrib/Short-refcard.pdf>
- R search engine: <http://www.rseek.org/>
- Webinar: FHWA's TMIP Webinar series included [a webinar on travel modeling using R](http://tmip.fhwa.dot.gov/webinars/usingR) in February 2011 (<http://tmip.fhwa.dot.gov/webinars/usingR>)

## Installing SmartGAP

### *Unzipping SmartGAP.zip*

SmartGAP is provided in a .zip compressed file, “SmartGAP.zip”. Once the zip file is downloaded to your computer, install it by using a zip file utility to extract the files to a directory on your computer, e.g. C:\SmartGAP\. The files will extract into the directory structure required to run the model (Figure 3-1).



*Figure 3-1: SmartGAP Directory Structure*

### *Dependencies Directory*

This directory contains a specific version of the TclTk2 package for R that was used to develop the GUI for SmartGAP and is provided to ensure certain required functions in used in TclTk2 package behave as expected. These files should not be modified.

### *Projects Directory*

In this directory there is one folder per project. The “Demo Project” folder contains an example project demonstrating the model. Each project directory contains a “base” scenario and other policy scenario folders as they are created. There are no caveats for naming the future

scenario directories except that they should not be called “parameters” as that would create a conflict with the parameters folder. Each scenario directory includes two subdirectories: inputs and outputs. The inputs directory includes all of the input files needed to specify a scenario. The outputs directory contains all of the output files that are produced by the model. Each project includes a parameters folder that holds editable model parameters that can be edited so that they are specific to a particular project.

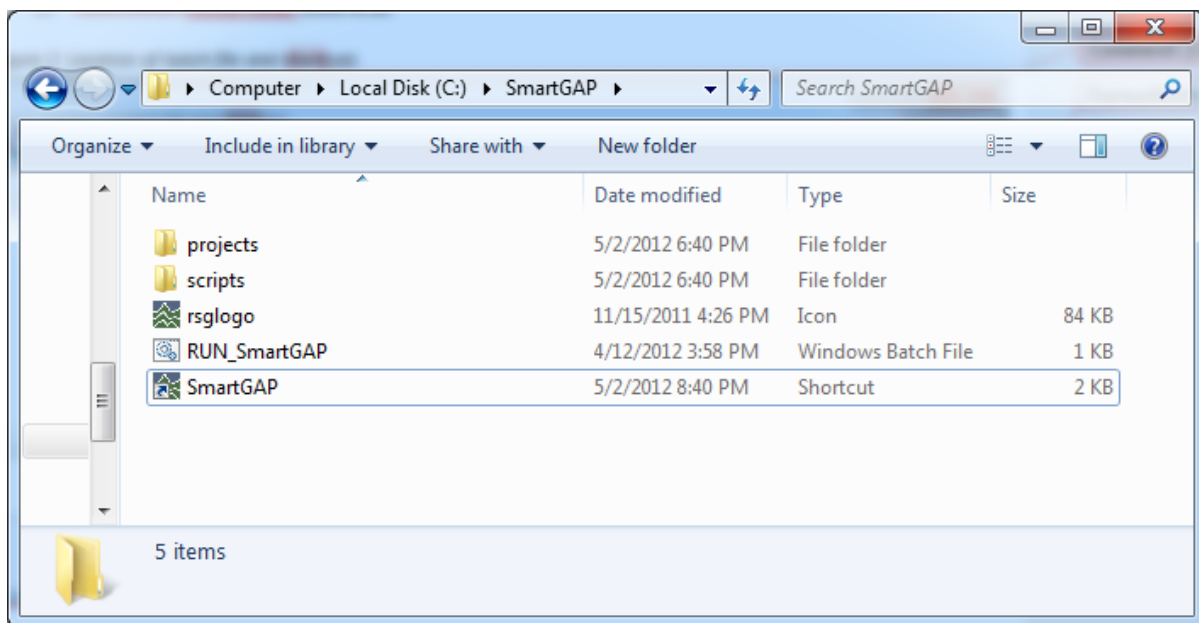
### *Scripts Directory*

This directory contains all of the R scripts that run portions of SmartGAP and the scripts that define the GUI. It also contains an .RData file (an R binary file) that contains functions, model specifications, and data tabulations used by the various model components. These files should not be modified.

### *Setting up the batch file and shortcuts*

Two files require editing in order to complete the installation of SmartGAP. These two files are located in the main root of the installation of SmartGAP – for example, if you unzip SmartGAP to C:\SmartGAP\, you will see them in that directory (Figure 3-2).

1. RUN\_SmartGAP.bat
2. SmartGAP shortcut



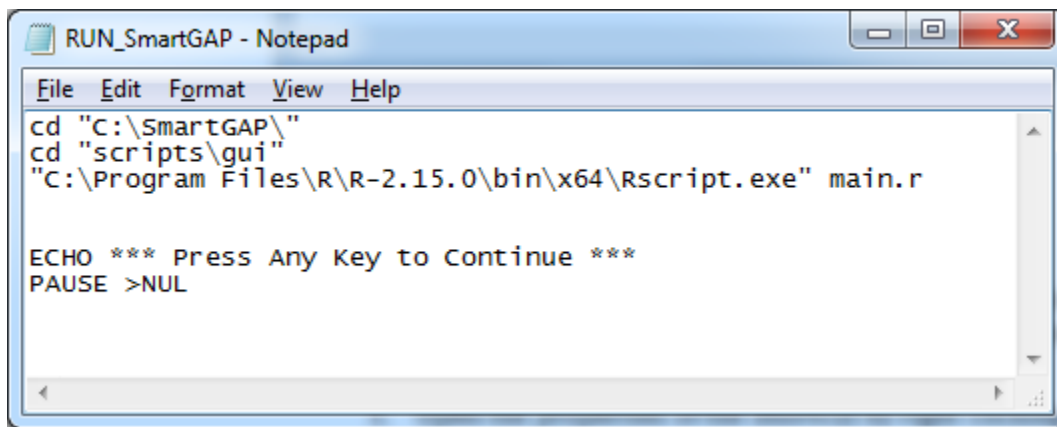
*Figure 3-2: Location of batch file and shortcuts*

### *RUN\_SmartGAP.bat*

RUN\_SmartGAP.bat is a batch file that calls the r script that opens the SmartGAP graphical user interface (GUI). It must be editing to correct the path to the installation of R on

your computer and to the installation location of SmartGAP. Figure 3-3 shows RUN\_SmartGAP.bat. Follow these steps to update it for your installation (note that these are windows specific instructions):

1. Open RUN\_SmartGAP.bat by right clicking on the file in windows explorer and selecting “Edit” to open the file in a text editor
2. On the first line replace “C:\SmartGAP” with a different path if you unzipped SmartGAP to a different location on your computer.
3. On the third line replace “C: \Program Files\R\R-2.15.0\bin\x64\RScript.exe” with the location of the RScript.exe executable for the installation of R on your computer.
4. Save your changes and close RUN\_SmartGAP.bat

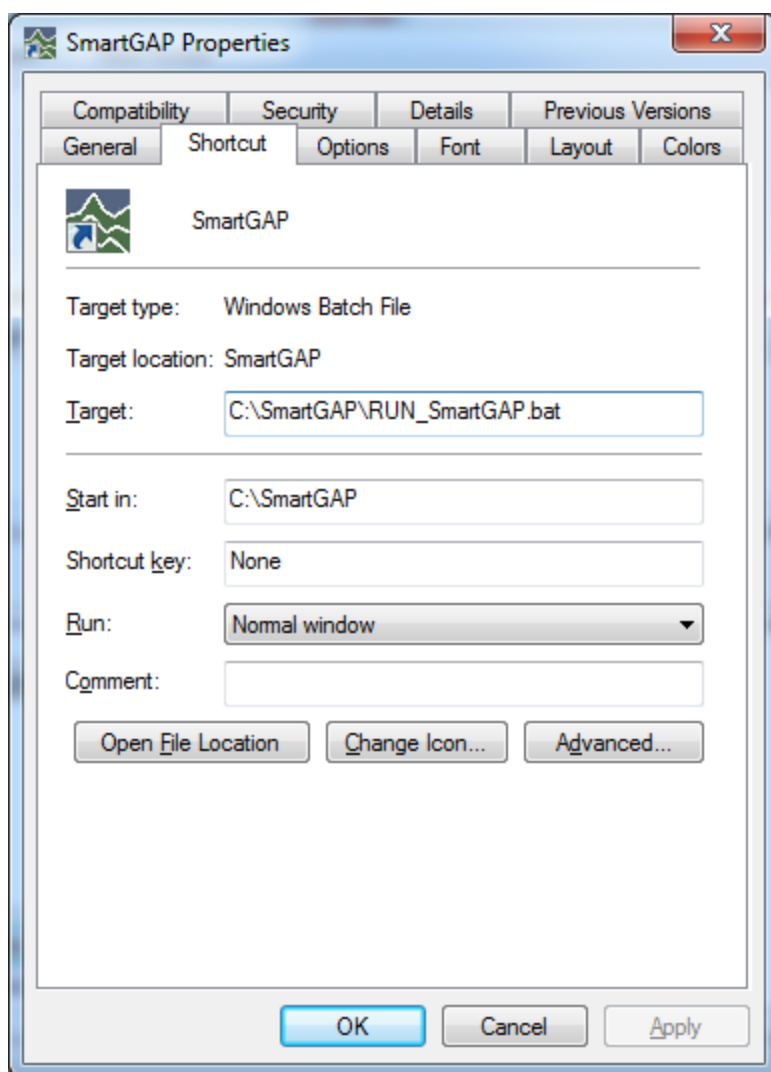


*Figure 3-3: RUN\_SmartGAP.bat*

#### *SmartGAP Shortcut*

Check that the SmartGAP shortcut points correctly to your installation of SmartGAP. Follow these steps to update it for your installation (note that these are windows specific instructions):

1. Open the properties of the shortcut by right clicking on the shortcut and selecting “Properties” in the pop-up menu. The window shown in Figure 3-4 will appear.
2. Set the Target field to match the path location for RUN\_SmartGAP.bat (e.g. C:\SmartGAP\RUN\_SmartGAP.bat)
3. Set the Start in field to match the installation location of SmartGAP (e.g. C:\SmartGAP)
4. Click “OK”
5. You can move the shortcut to a convenient location such as your desktop



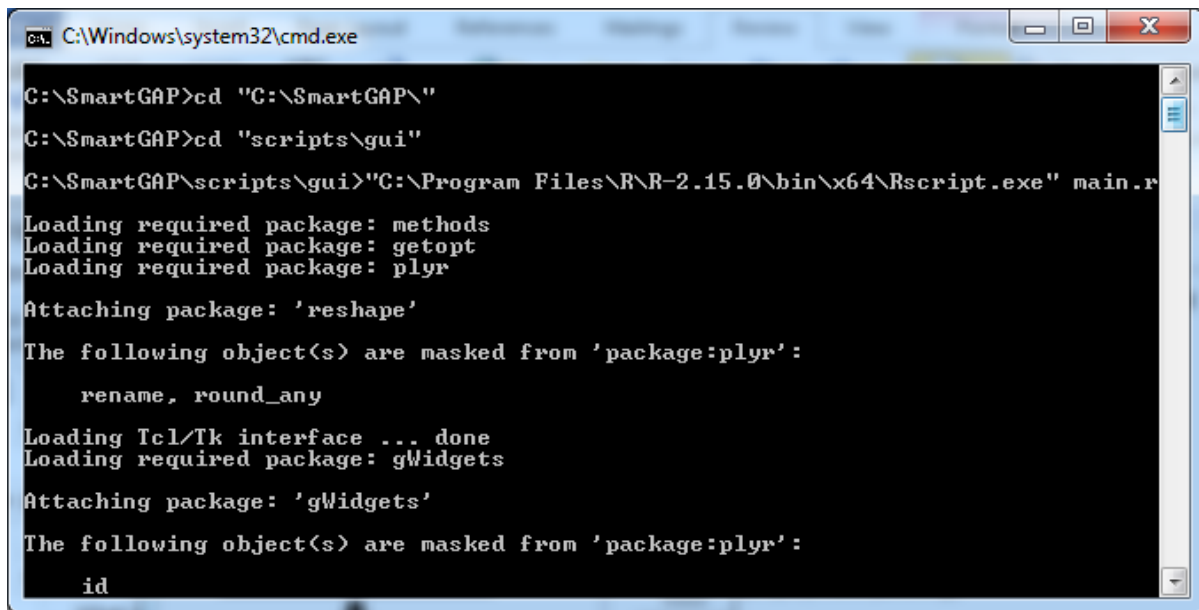
*Figure 3-4: SmartGAP Shortcut Properties Window*

### *Opening SmartGAP*

Open SmartGAP by double clicking on the SmartGAP shortcut (or by double clicking directly on the RUN\_SmartGAP.bat batch file). As SmartGAP is opening, an output console as shown in Figure 3-5 opens and displays script output. The GUI will then open in a separate window as shown in Figure 3-6. Do not close the output console – it must remain open while SmartGAP is in use.

The process of **opening SmartGAP for the first time** will take a few seconds to a couple of minutes and **requires internet access**. This is because SmartGAP uses several R packages, which are add-in libraries to R that can be downloaded from CRAN. They are not by default included with your installation of R or with SmartGAP. When SmartGAP is opened the code checks for the presence of these packages on your computer, and if it does not find them it will download them from the CRAN website. Once they have been downloaded, opening SmartGAP does not require internet access.

Depending on the operating system and settings of your computer and your administrative rights there can occasionally be problems with installing R packages. If errors occur during the download and loading of packages as SmartGAP opens, please refer to the two platform specific FAQ sites that contain detailed installation instructions for Windows (<http://cran.r-project.org/bin/windows/base/rw-FAQ.html>) and Mac OS X (<http://cran.r-project.org/bin/macosx/RMacOSX-FAQ.html>) and discuss any known problems with the various versions of R and their interactions with different combinations of operating systems and settings.



```
C:\Windows\system32\cmd.exe

C:\SmartGAP>cd "C:\SmartGAP\"
C:\SmartGAP>cd "scripts\gui"
C:\SmartGAP\scripts\gui>"C:\Program Files\R\R-2.15.0\bin\x64\Rscript.exe" main.r
Loading required package: methods
Loading required package: getopt
Loading required package: plyr
Attaching package: 'reshape'
The following object(s) are masked from 'package:plyr':
  rename, round_any
Loading Tcl/Tk interface ... done
Loading required package: gWidgets
Attaching package: 'gWidgets'
The following object(s) are masked from 'package:plyr':
  id
```

*Figure 3-5: Rscript cmd console window*

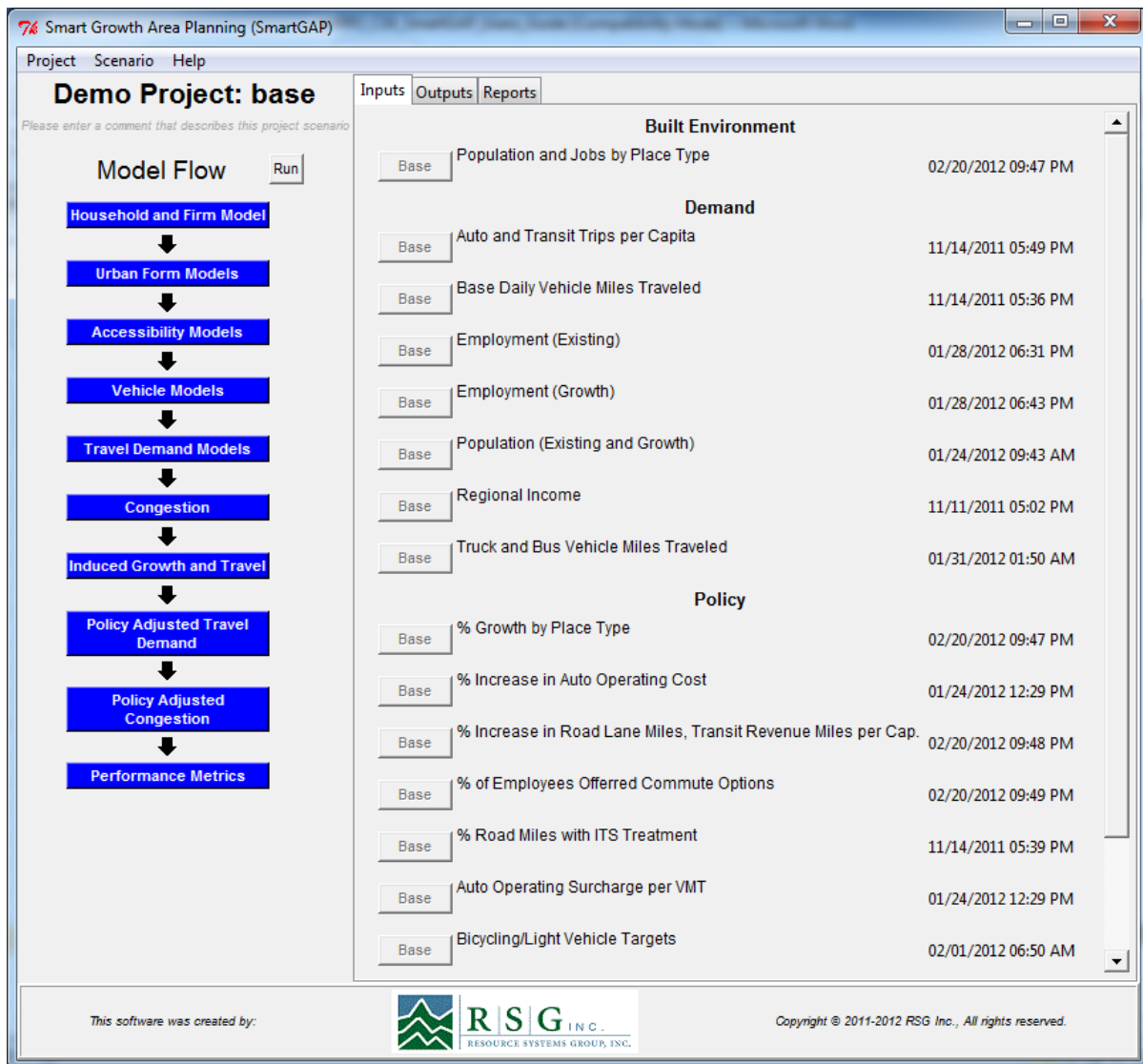


Figure 3-6: SmartGAP GUI on opening

## CHAPTER 4. RUNNING SMARTGAP

### About the User Interface

Figure 3-6 above shows the appearance of the user interface when it is opened. The model opens in the base scenario of the demo project, an example project that is supplied with the software so that users can see a complete set of inputs and try running the model without needing to first create a complete set of input files. Figure 4-1 identifies the major components of the user interface. The functionality of these components is discussed below.

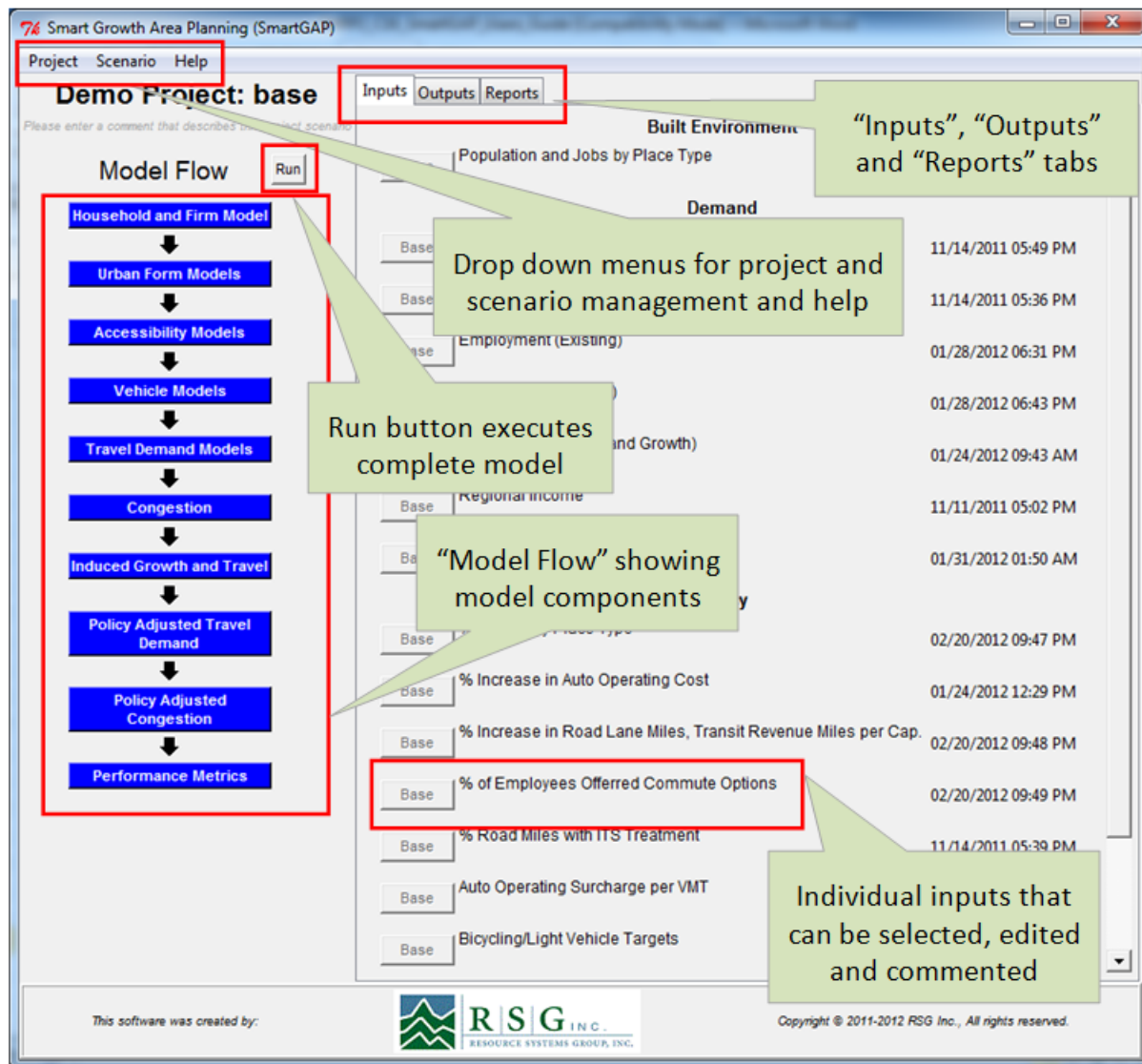


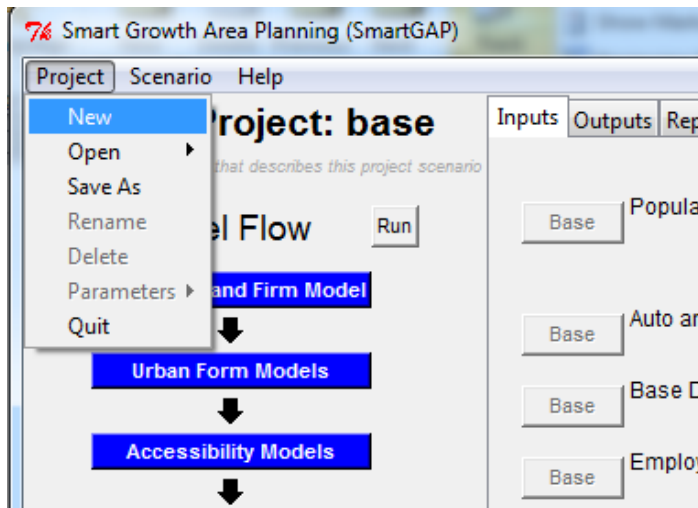
Figure 4-1: Components of the user interface

### The Project Menu

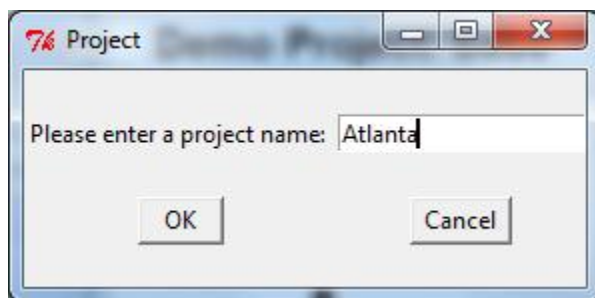
The project menu allows creation of new projects, navigation between projects, and editing of model parameters that are used in scenarios across a project. The distinction between

projects and scenarios is discussed in more detail below, but essentially a project represents a holder for a set of scenarios testing alternative policies within a specific geography.

Figure 4-2 shows the “new” command on the project menu that creates a new project. Clicking on the “new” command pops up the project naming dialog (Figure 4-3). Once the project is named, the model creates the new project and an initial “base” scenario. The “save as” command operates in the same way as the “new” command except that rather than creating an empty project with just an empty base scenario, it copies the contents of the current project.



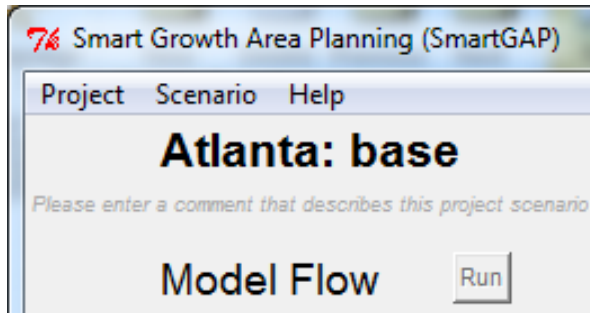
*Figure 4-2: Starting a new project using the project menu*



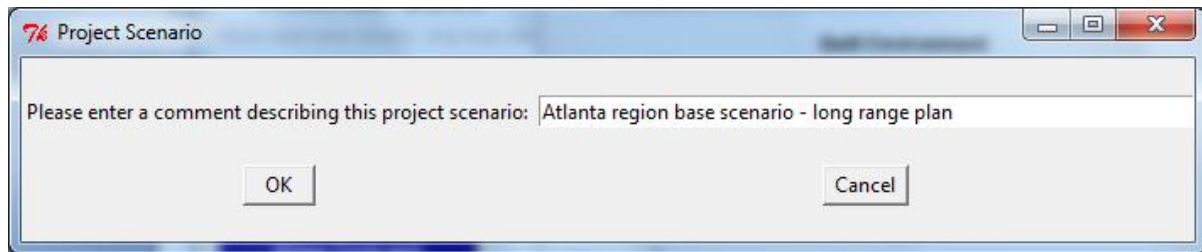
*Figure 4-3: The new project name dialog box (also launched when save as is selected)*

The model user can click on the text below the name of the project (Figure 4-4) to launch the scenario comment box that allows the model user to enter a brief description of the scenario (Figure 4-5). The comment appears below the title of the project and scenario (Figure 4-6),

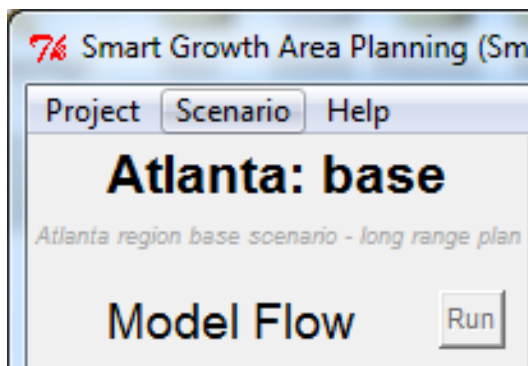




*Figure 4-4: The new project is opened after naming*



*Figure 4-5: Scenario comment dialog box*



*Figure 4-6: Comment appears below the project title: scenario title heading*

The “open” command on the project allows for navigation between the existing projects that the model user has created (Figure 4-7). The demo project is supplied with the software.

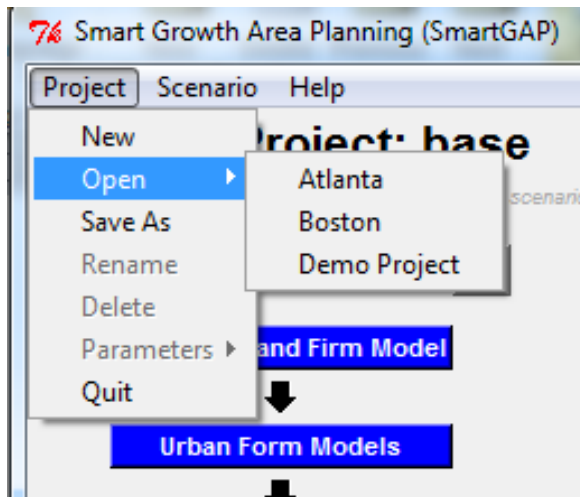


Figure 4-7: Project menu open command allows navigation between the existing projects

The “rename” and “delete” commands are active in user created projects and allow the project to be renamed or deleted. The commands are disabled when the demo project is open. Also active when a user created project is open is the parameter menu that allows various model parameters to be viewed and edited (Figure 4-8). The model user is warned about the consequences of editing parameters (Figure 4-9) before they can proceed to the parameter editor (the parameter editor is identical to the input data editor, shown in Figure 4-18)

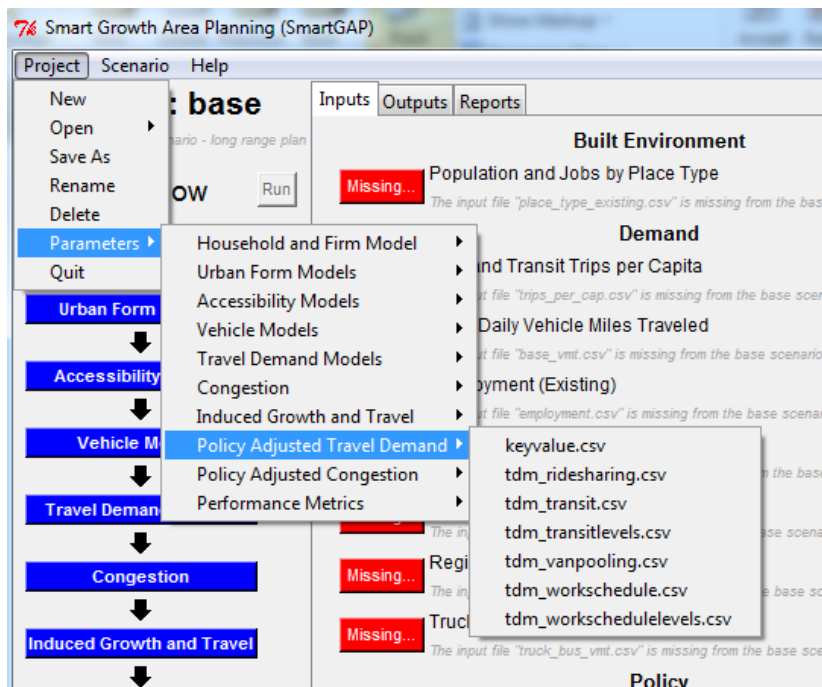
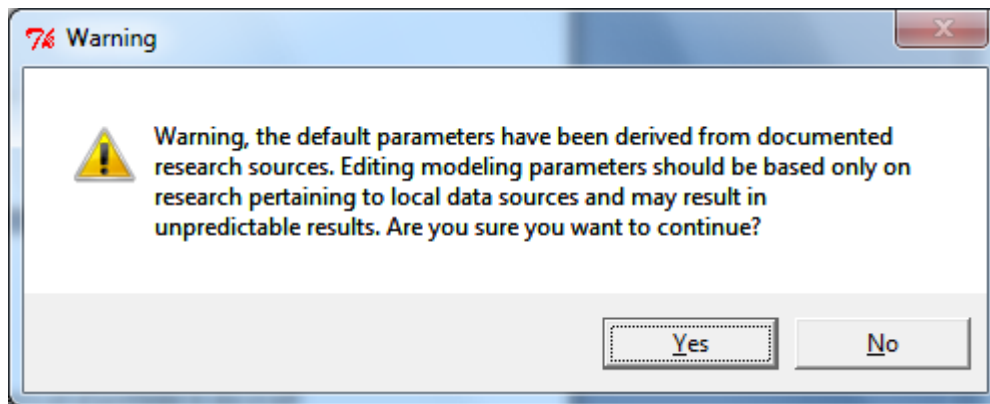


Figure 4-8: Project menu parameters command allows users to select a set of parameters to view or edit



*Figure 4-9: Before being allowed to edit parameters, users are warned about the possible consequences of doing so*

#### *Setting the model base and forecast year*

There are two parameters that the user is likely to want to alter from their default values: the Base Year and Future Year for their model runs. The keyvalue.csv parameter file can be opened from the project > parameters menu and is linked to all of the model components. Figure 4-10 shows it displayed in the edit window. The values should correspond with those used for the population data and other inputs as discussed in the Developing Input Data section of the user's guide and must be on increments of 5 years between 1990 and 2050 (e.g. 1990, 1995, 2000, ..., 2045, 2050)

The image shows a window titled "Edit keyvalue.csv" containing a table with two columns: "key" and "value". The table lists 14 parameters with their corresponding values. At the bottom of the window are "Save" and "Cancel" buttons.

	key	value
1	AnnVmtInflator	365.000
2	BaseCostPerMile	0.040
3	BaseYear	2005.000
4	BudgetProp	0.100
5	FuelCost	1.820
6	FutureYear	2035.000
7	GasTax	0.424
8	HhDvmtToRoadDvmt	0.950
9	LtTruckProp	0.450
10	MjPerGallon	121.000
11	PoundToKilogram	0.450
12	TranAdjFactor	1.120
13	TruckVmtGrowthMultiplier	1.000
14	WorkVmtProp	0.250

*Figure 4-10: Keyvalue.csv parameter file*

## Browsing to Inputs to Create a Base Scenario

When a new project is created using the “new” command, all of the inputs are shown as missing (Figure 4-11) and the user must browse to files that represent each of the inputs. Clicking on the input button (“Missing...” in this state) opens a contextual menu that only allows browsing (Figure 4-12). In the browse window (Figure 4-13) the model user can browse to an input file on their computer, which is then copied to the project folder and renamed using the naming convention for the model input files. Figure 4-14 shows a partially filled base scenario, with several input files selected.

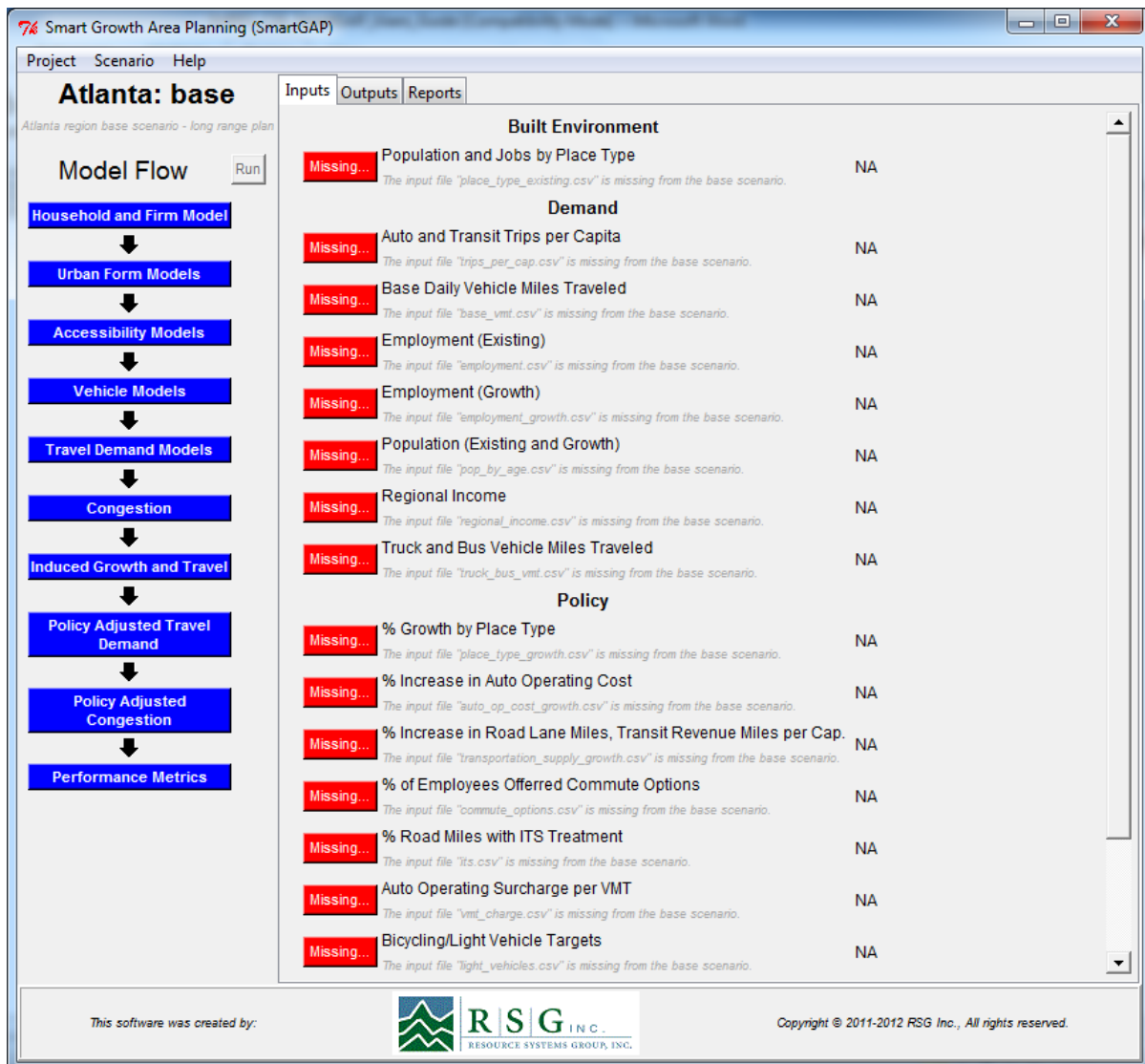


Figure 4-11: A new project with no inputs selected

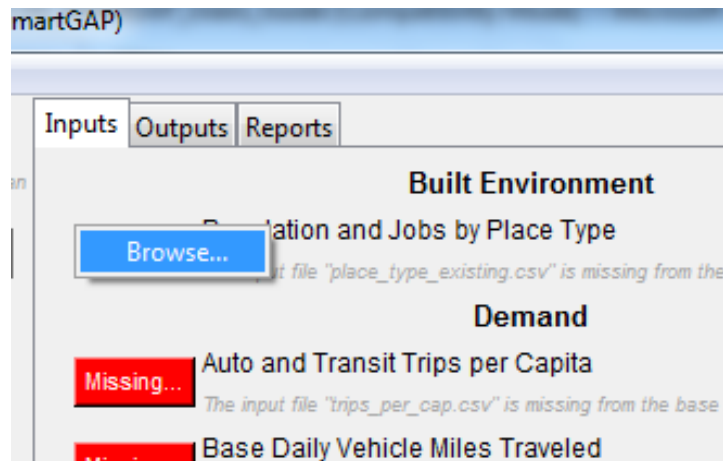


Figure 4-12: In the base scenario for a project, browse to an input file

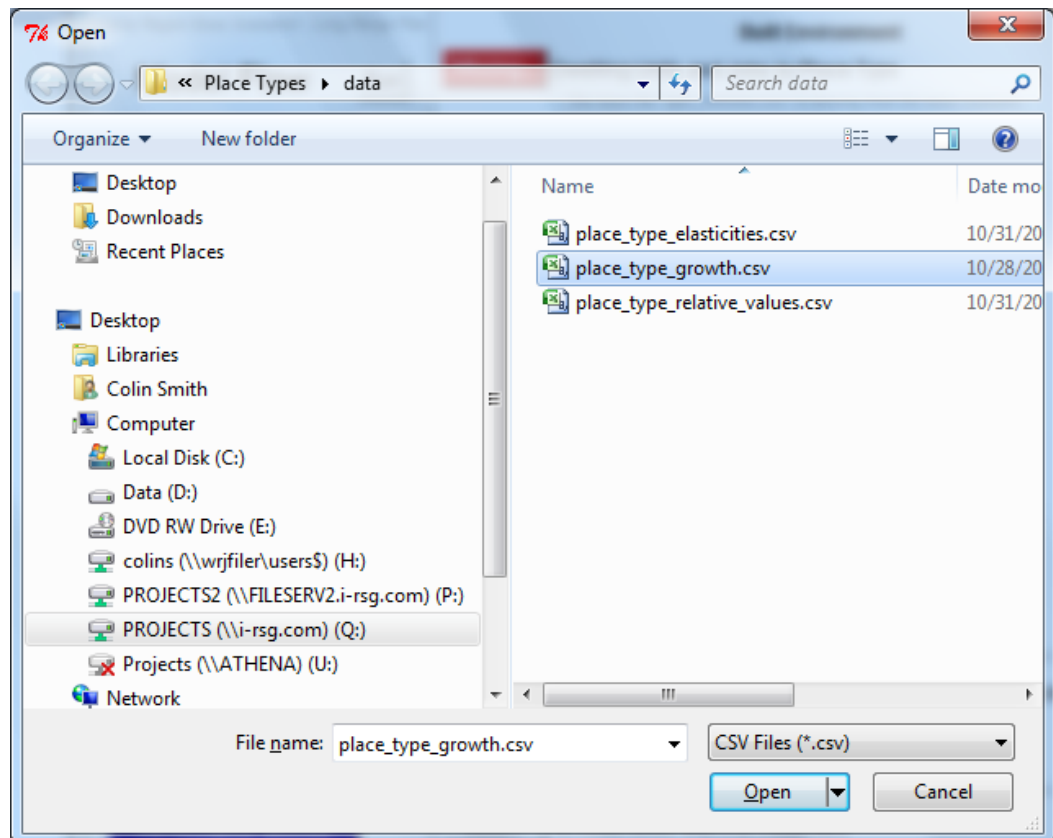


Figure 4-13: Browse dialog to select files

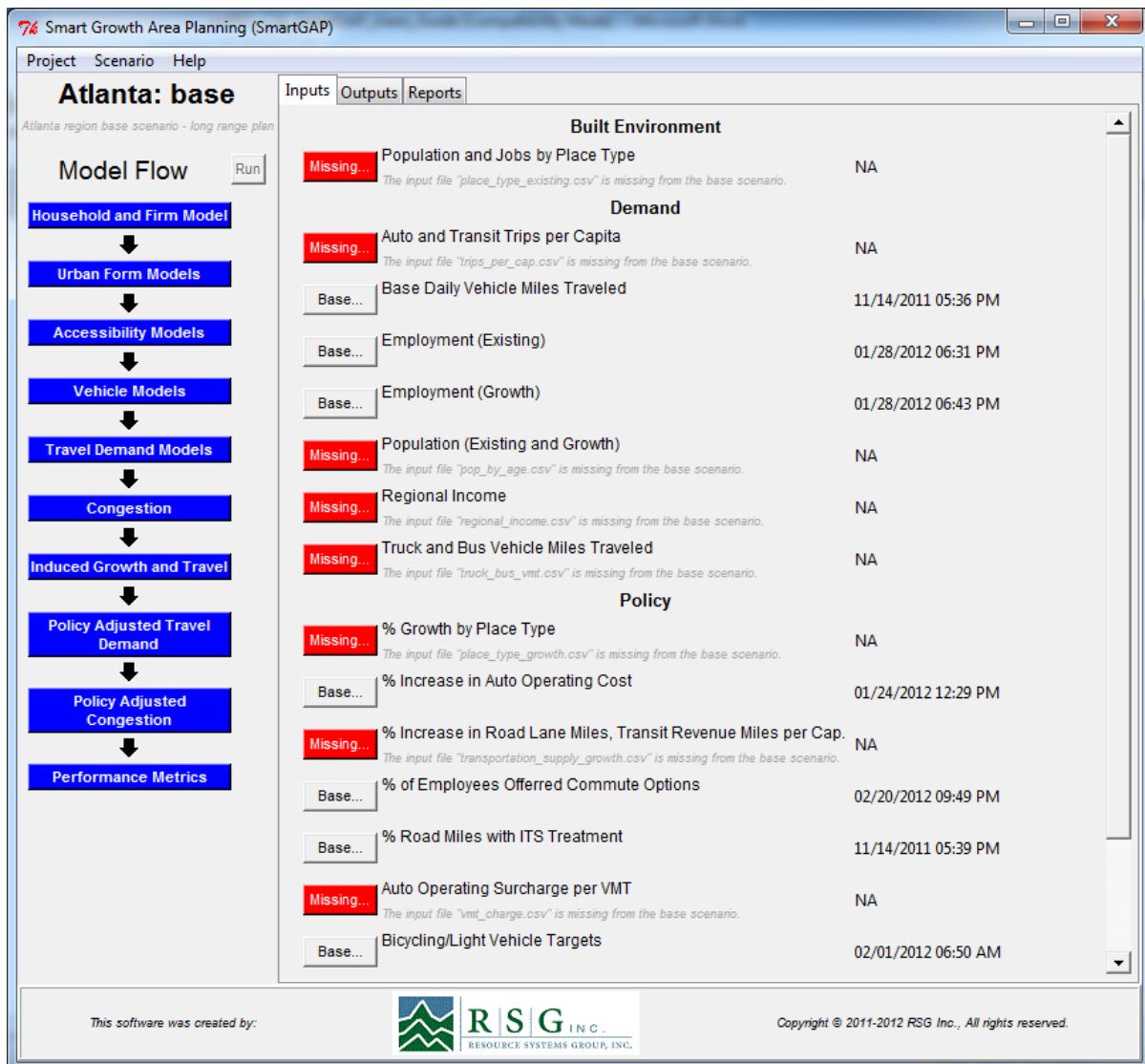
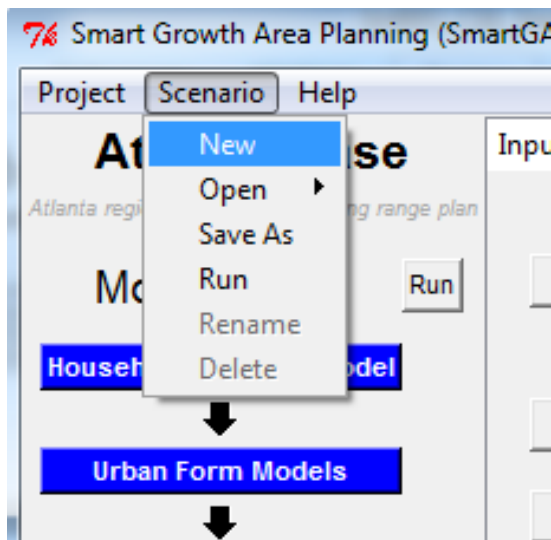


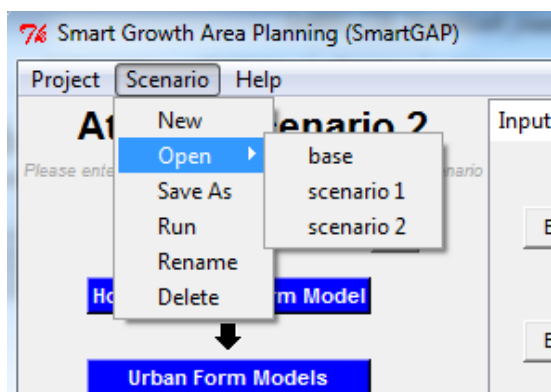
Figure 4-14: Partially filled base scenario

## The Scenario Menu

The scenario menu allows creation of new scenarios, navigation between scenarios, running scenarios, and the renaming and deletion of scenarios (except for the base scenario that cannot be either renamed or deleted). Figure 4-15 shows the “new” command on the scenario menu that creates a new scenario which is identical to the base scenario. Clicking on the “new” command pops up the scenario naming dialog. Once the scenario is named the model user can enter a comment describing the scenario as shown above in Figure 4-5. The open command (Figure 4-16) can be used to navigate between all of the scenarios created within the currently open project. The “save as” command operates in a similar way to the “save as” project command: it makes a copy of the currently open scenario, which can then be adjusted by the model user.



*Figure 4-15: Creating a new scenario menu using the scenario menu*



*Figure 4-16: Navigating between scenarios within a project*

### *Defining a Scenario*

A scenario is defined and distinguished from the base by either editing and altering input files or browsing to alternative input files. By default, a new scenario starts with references back to the base inputs (as indicated by “Base...” on the button adjacent to the input). Selecting “Edit...” from the contextual menu that pops up when the input button is selected (Figure 4-17) copies the base input to the scenario folder and opens it for editing. The editor opens the input file in a spreadsheet style window where edits can be made and saved (Figure 4-18).

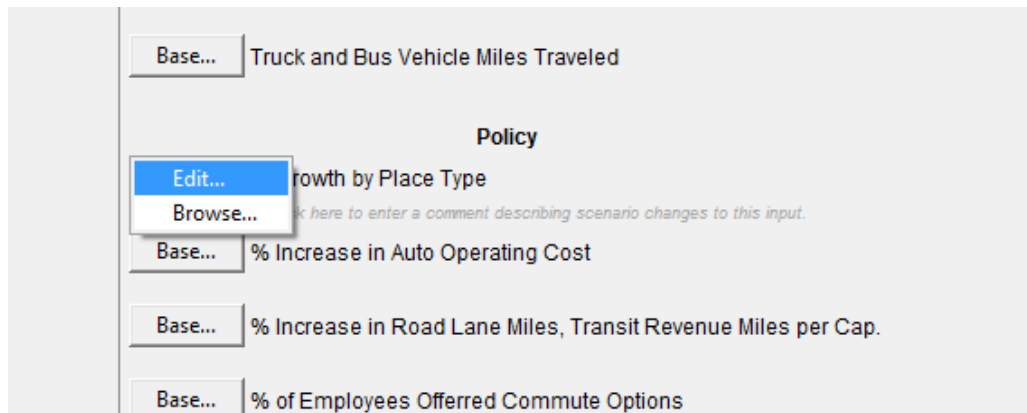


Figure 4-17: Selecting an input file to edit

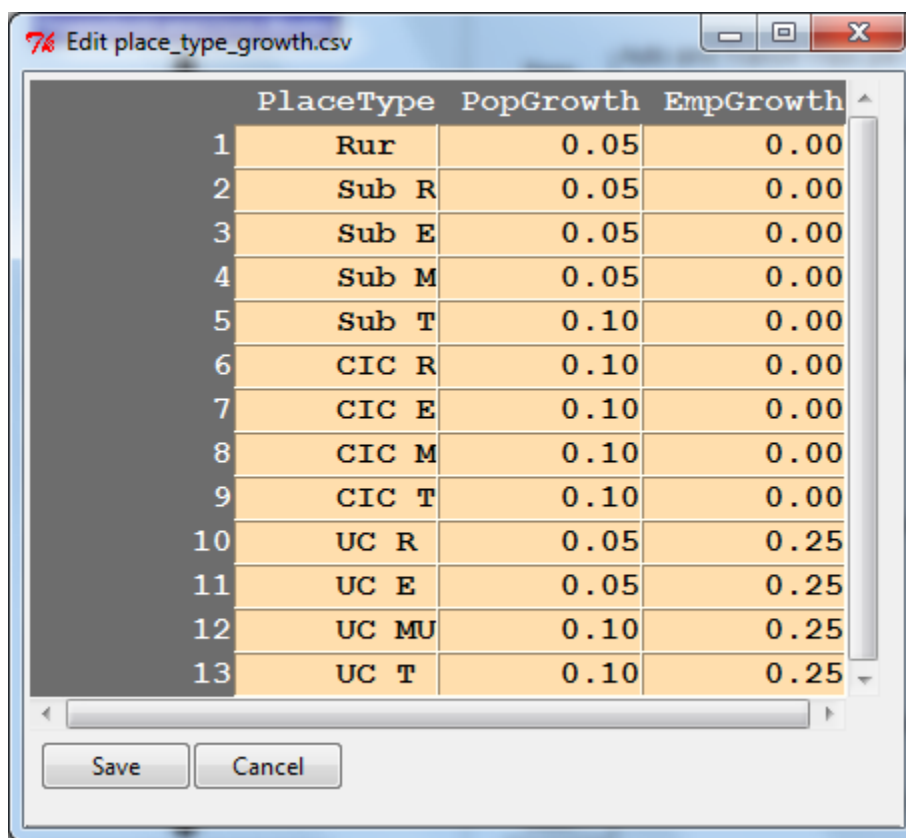
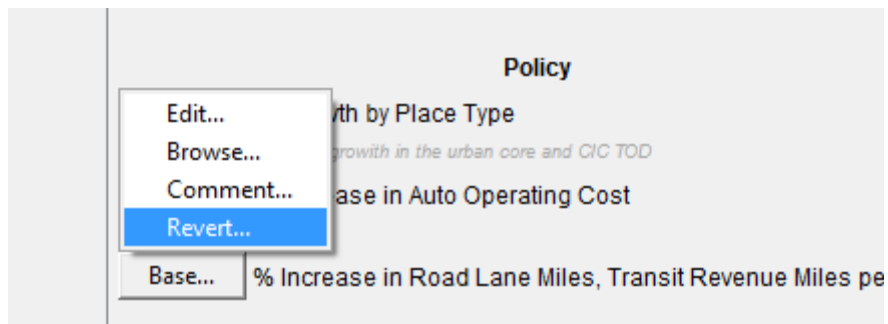


Figure 4-18: The input file editor

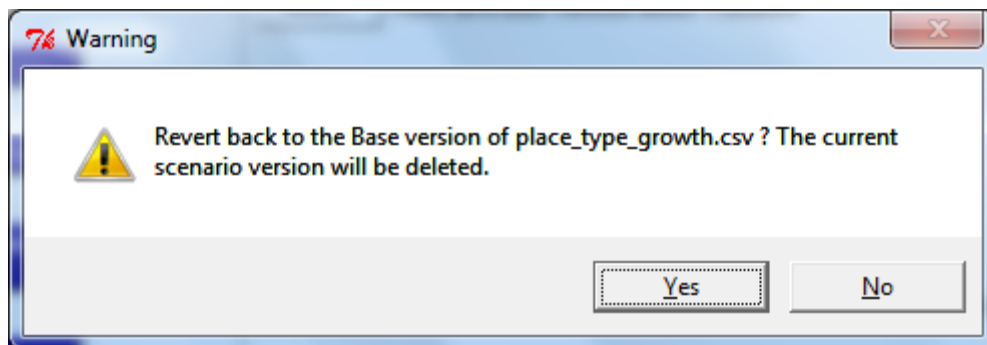
All inputs that are different from the base inputs (either through editing or browsing to an alternative file) are marked with “Scenario...” on the input button. Once an input file has been changed, two additional commands appear on the contextual menu that appears when the input is clicked (Figure 4-19). The “revert” command allows a model user to change back to the base version of the input file. Selecting this command will delete any edits to the input file so the model user is warned (Figure 4-20). The “comment” command allows model users to launch the input comment dialog (Figure 4-21). Model users can enter a brief comment that describes the



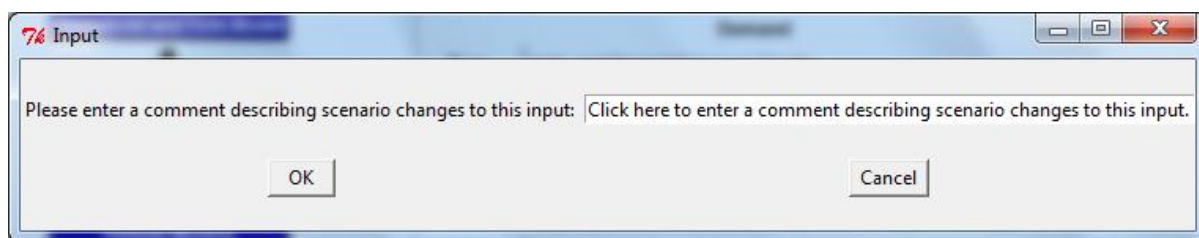
changes that they have made to the input file. Scanning down the input file comments allows the user to quickly recall the set of changes that they have made to the input files that encompass the scenario (Figure 4-22).



*Figure 4-19: Input menu for a scenario file*



*Figure 4-20: Revert warning*



*Figure 4-21: Input comment dialog box*

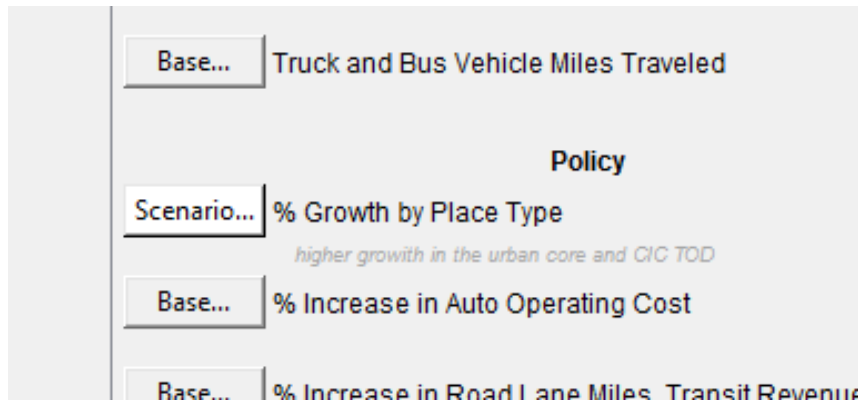
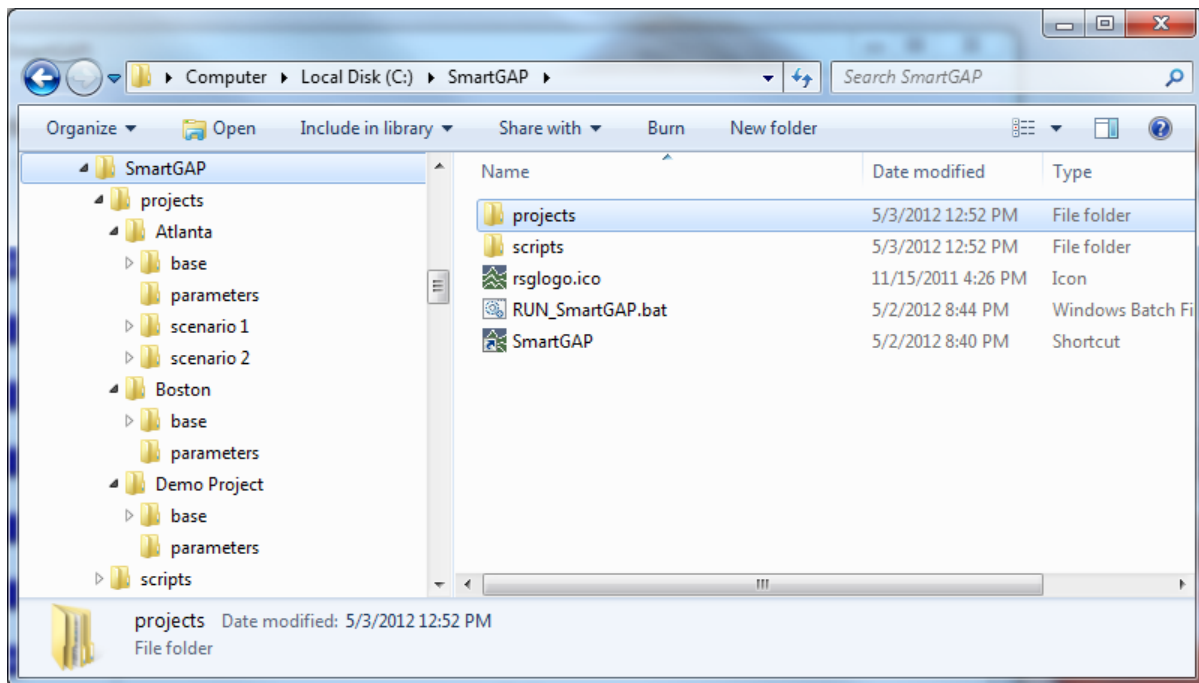


Figure 4-22: Completed input file comment

### Scenario Management

The software builds a file structure that manages two levels of work: projects and scenarios. A project is intended as a container for a set of scenarios. The software is created with the intention that the scenarios within a project will encompass the same geographical area so that the outcomes of alternative development scenarios can be evaluated and compared.

Figure 4-23 shows the file structure that the software uses. The model and scripts folders hold the various script files and model code that encompass the software. The projects folder holds all of the individual project folders – in this case “Atlanta” and “Demo Project” (which is supplied with the software). Within each project folder are the scenario folders, e.g. “base” and “scenario 1” in the “Atlanta” project. There is also a parameters folder that contains the parameters for that project; these will be the default parameters unless the model user has edited them. Each project is created with a base scenario and then the model user can add additional scenarios. Within the scenario folders is a directory for inputs and one for outputs. The inputs are stored as .csv files, while the outputs are stored as .rdata files which can be exported to .csv format using the software or opened in R.



*Figure 4-23: File structure showing projects and scenarios*

## The Help Menu

The help menu is the final menu in the user interface. This user's guide can be accessed using this menu.

## Running the Model

Once a scenario is loaded with inputs, the model can be run. The model can either be run in its entirety or each component can be run individually. The "run" command on the scenario menu and the run button on the user interface both launch a complete run. Figure 4-24 shows a run in progress.

As soon as the run button is clicked, the main window of the interface switches from showing the inputs pane to showing the outputs pane, the run button changes from saying "run" to saying "cancel", the first model step changes from blue to yellow, and a timer adjacent to the first model step starts to count. As the run progresses, successfully completed model components change from yellow to green, and the timer stops at the current elapsed model run time. A run can be halted in mid-stream by clicking the "cancel" button (Figure 4-25). The model step that is currently being executed will show red to indicate that it did not complete successfully. A single step of the model can be run by right clicking on the model step in the model flow chart and selecting "run step" (Figure 4-26).

Run times vary considerably depending on the computer system used for running the model and, more importantly, the size of the region's population and its number of businesses. Pilot tests were performed on a relatively new desktop computer with Intel Core 2 Quad CPU Q9400 @ 2.66 GHz, 8 GB RAM, and a 64 Bit Windows 7 Ultimate operating system. The

following run times were observed for a single scenario, which increased close to linearly as the population of the region increased:

- Cecil County, Maryland, 2035 population of 170,000: 2-3 minutes
- Thurston County, Washington, 2040 population of 425,000: 4-5 minutes
- Montgomery County, Maryland, 2035 population of 1.1 million: 15 minutes
- Portland Metropolitan region, 2035 population of 2.3 million: 25 minutes
- Atlanta Region, 2040 population of 8.3 million: 1 hour 45 minutes

**Smart Growth Area Planning (SmartGAP)**

Project Scenario Help

**Demo Project: base**

Please enter a comment that describes this project scenario

**Model Flow** Cancel

Household and Firm Model 00:24

Urban Form Models 00:36

Accessibility Models

Vehicle Models

Travel Demand Models

Congestion

Induced Growth and Travel

Policy Adjusted Travel Demand

Policy Adjusted Congestion

Performance Metrics

**Community Impacts**

View	Export	Accident Rates
View	Export	Job Accessibility by Income Group
View	Export	Walking Percentage Increase

**Direct Travel Impacts**

View	Export	Daily Transit Trips
View	Export	Daily Vehicle Miles Traveled
View	Export	Daily Vehicle Trips
View	Export	Peak Travel Speeds by Vehicle Type
View	Export	Vehicle Hours of Delay
View	Export	Vehicle Hours of Travel

**Environment and Energy Impacts**

View	Export	Fuel Consumption
View	Export	Greenhouse Gas Emissions

**Financial and Economic Impacts**

View	Export	Annual Transit Operating Cost
View	Export	Annual Traveler Cost (Fuel and Charges)
View	Export	Regional Infrastructure Costs for Highway
View	Export	Regional Infrastructure Costs for Transit

**Location Impacts**

View	Export	Regional Accessibility
------	--------	------------------------

**Summaries of Inputs**

View	Export	Employment
View	Export	Income
View	Export	Population

This software was created by: **RSG INC.** RESOURCE SYSTEMS GROUP, INC.

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Figure 4-24: Running the model

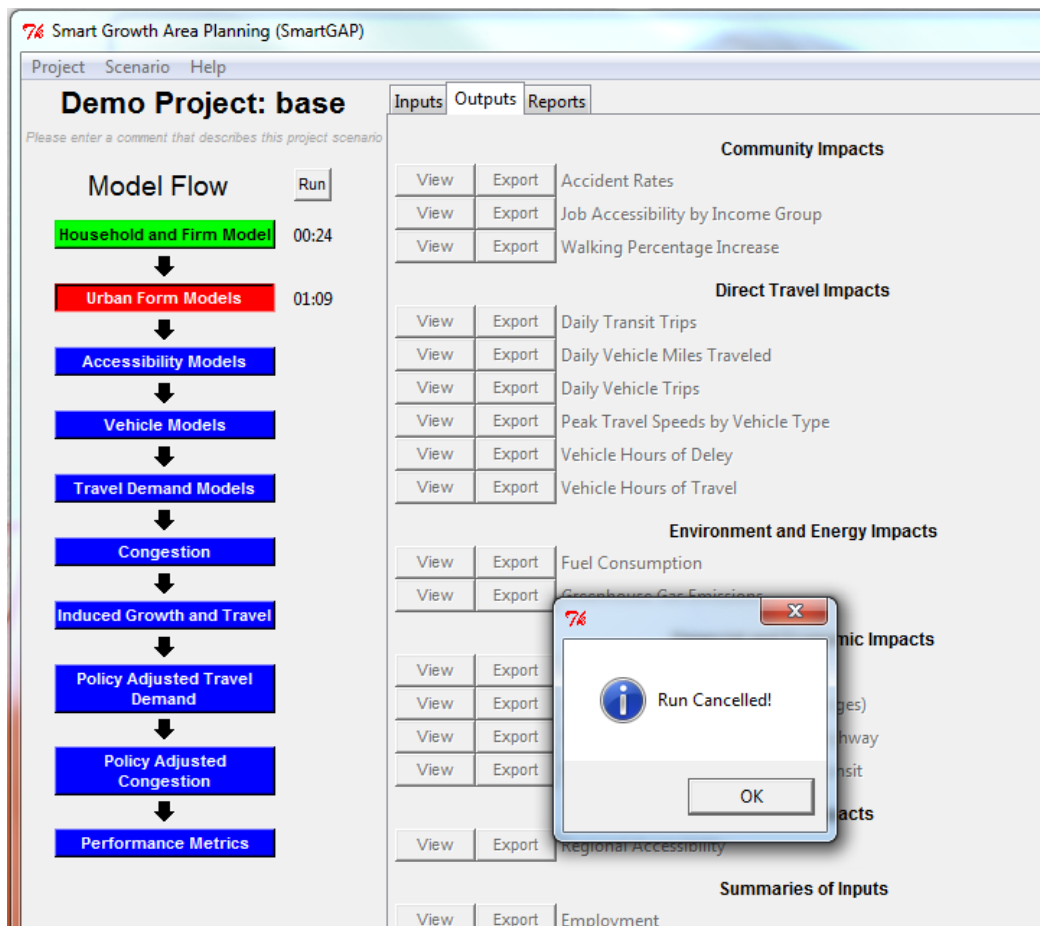


Figure 4-25: Stopping the model

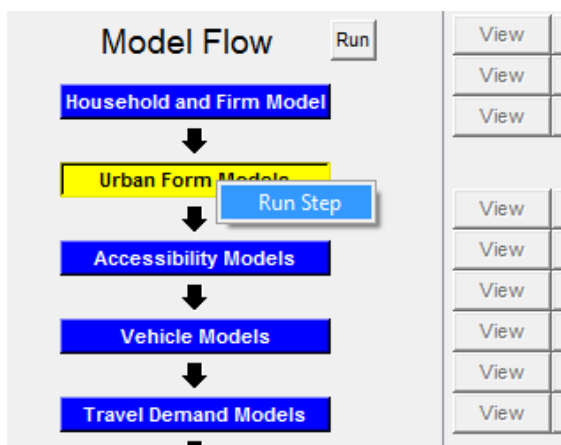


Figure 4-26: Running a single step of the model

## Outputs

The outputs tab shows a list of the outputs produced by the model (Figure 4-27 shows the output window before the scenario has been run when no outputs are available and Figure 4-28

shows the output window after the scenario has been run). The model writes out a set of “.Rdata” R binary files that contain tables of results for the various performance metrics that the model produces. As a model run progresses and these outputs are produced, they immediately become available to the model user: the view and export buttons become active to indicate that the outputs are available (many of the outputs are produced in the performance metrics model component, the final component, and so don’t become available until the model run is completed). The view button opens a tabulation of results in a spreadsheet style window, identical to that used for editing inputs (Figure 4-29). The export button launches a browse dialog that allows the model user to select a location to save the file to in comma separated value (.csv) format that can be opened by any standard text editor, spreadsheet software, or database software.

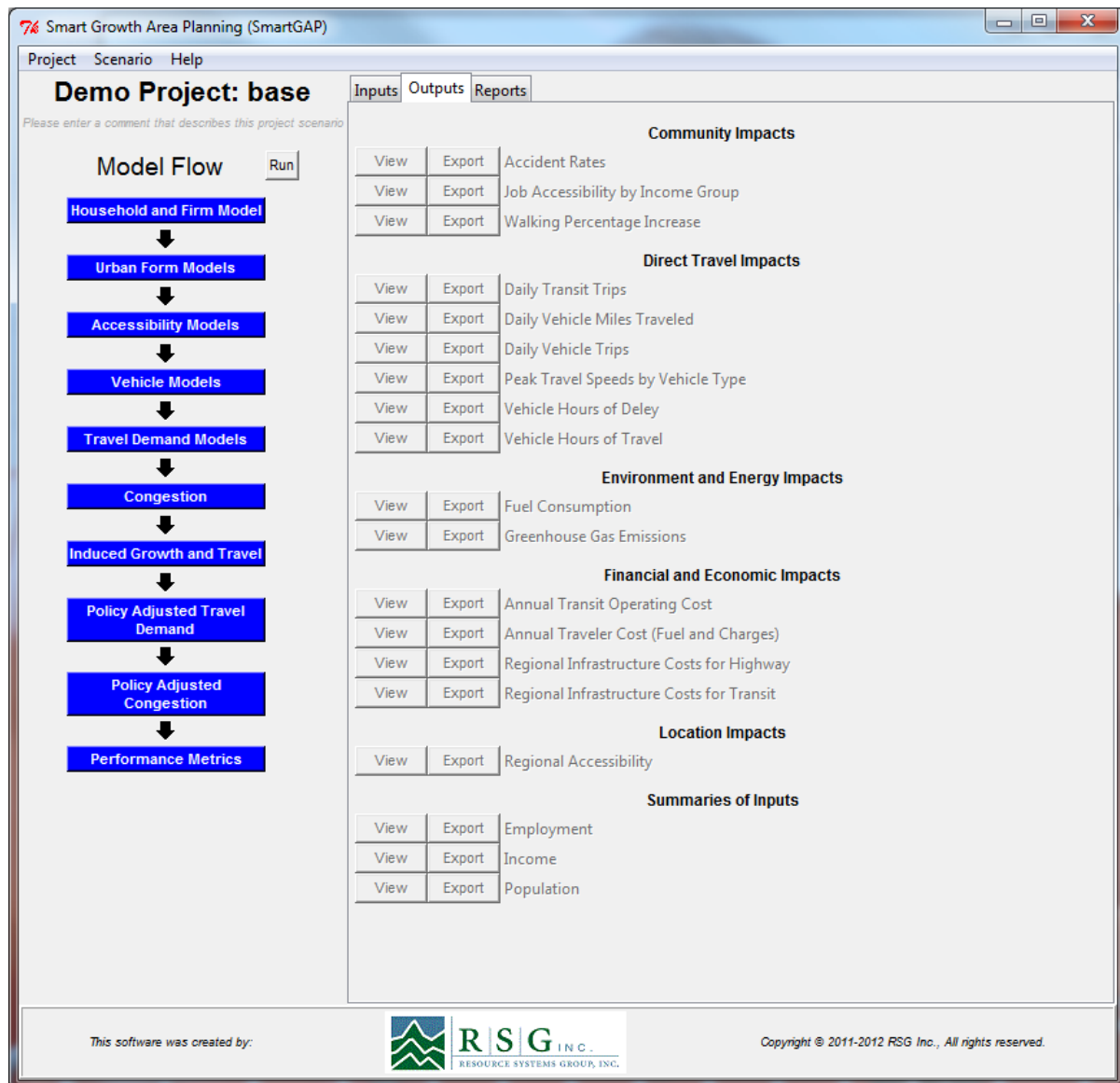


Figure 4-27: Model outputs tab before a scenario has been run

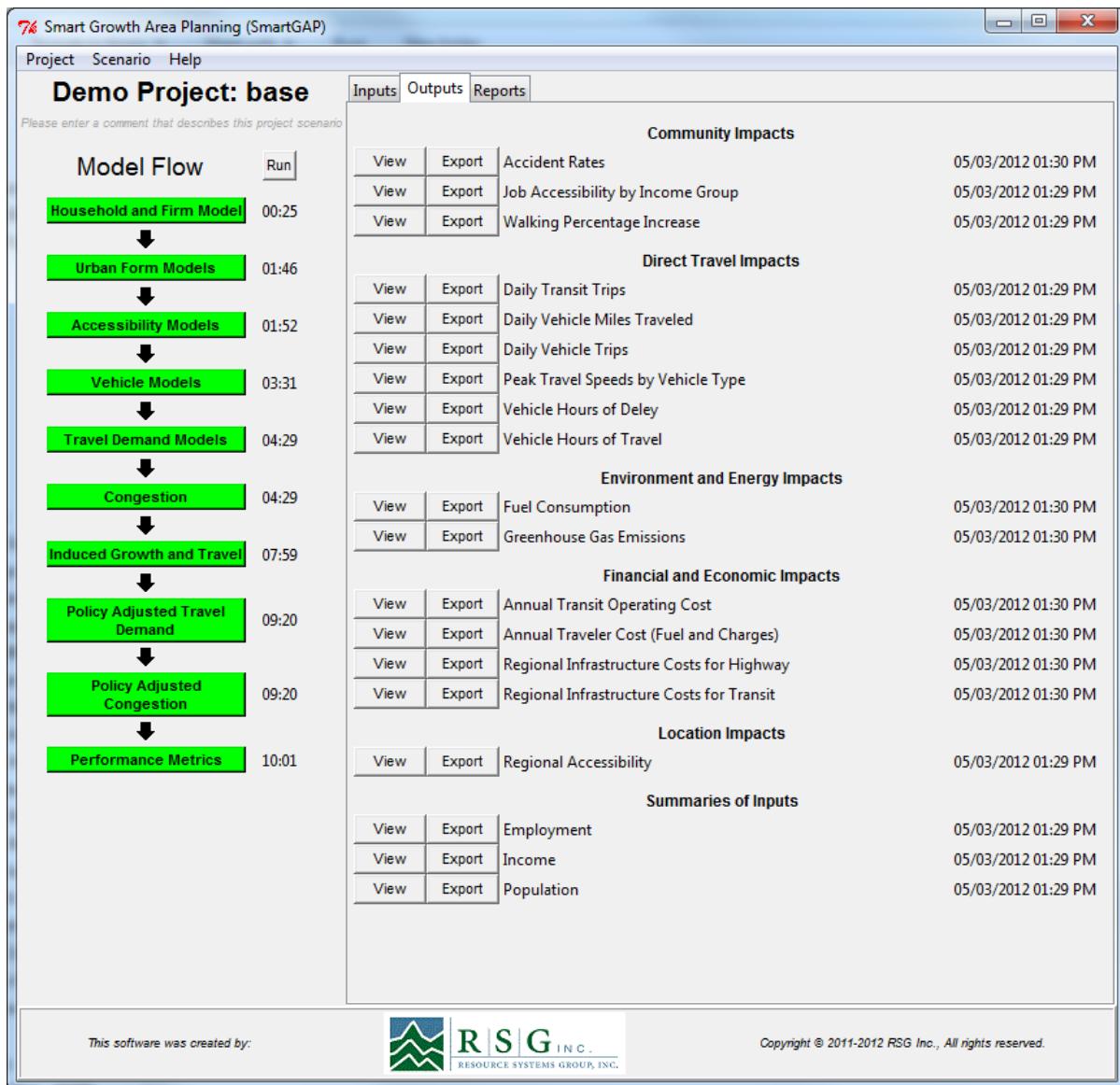
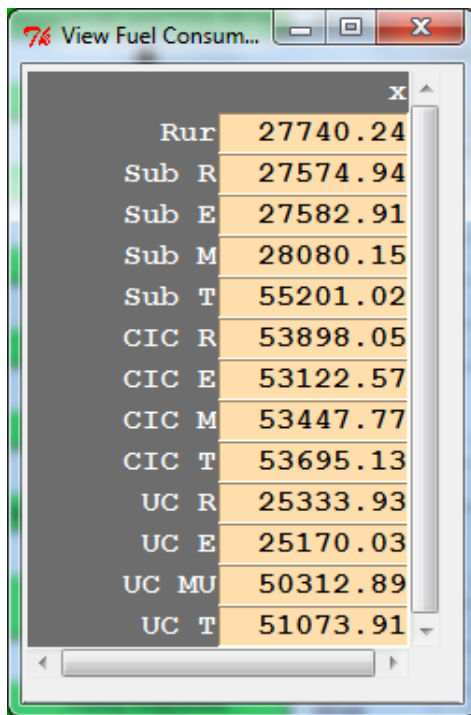


Figure 4-28: Model outputs tab after a scenario has been run



Category	Fuel Consumption
Rur	27740.24
Sub R	27574.94
Sub E	27582.91
Sub M	28080.15
Sub T	55201.02
CIC R	53898.05
CIC E	53122.57
CIC M	53447.77
CIC T	53695.13
UC R	25333.93
UC E	25170.03
UC MU	50312.89
UC T	51073.91

Figure 4-29: View window displaying the fuel consumption output

## Reports

The reports tab allows results for individual or multiple scenarios to be charted and compared. The charts can be viewing using the user interface or exported in a variety of file formats for incorporating in reports documenting scenario testing. Figure 4-30 shows the appearance of the reports tab when two scenarios have been run. There are several sets of check boxes, radio buttons, and buttons that allow the user to build a chart as follows:

- **Scenarios** – checking the scenarios check boxes includes the selected scenarios in the chart
- **Metric** – one metric can be selected for display on the charts
- **Aggregation** – the metrics are reported by the model at various levels of detail and the aggregation selection indicates the level of summary that the user wishes to see. Once a metric is selected only the aggregation levels applicable to that metric will be selectable. For example, Dvmt (daily vehicle miles traveled) is reported for the 13 place types. Selecting “Place Types” will show all 13 place types. Selecting “Area Types” will aggregate the results to the four area types. Selecting “Development Types” will aggregate the results to the five development types. The default aggregation level is “All” which displays the total value for the region for that metric.
- **Measure** – allows the users to choose to display the results as “Number” (absolute values), “Percentage” (percentages within the aggregation categories for each scenario), “Index (100)” (index comparison across scenarios for each aggregation category with the first scenario displayed indexed to 100 and other scenarios relative to that), or “Index (0)” (index comparison across scenarios for each aggregation category with the first scenario displayed



indexed to 100 and other scenarios relative to that, but then all of the values shifted to be relative to a base of zero) .

- **Plot** – displays a plot window
- **Export** – displays an export dialog allowing the user to browse to a location, name the file, and to choose a file format from .pdf, .jpeg, .png, .bmp, .tiff, .svg, .wmf, .ps, and .tex.

Figure 4-31 shows an example chart creating by selecting two scenarios, the Dvmt metric, the Area Types aggregation, the Number measure, and then clicking the Plot button.

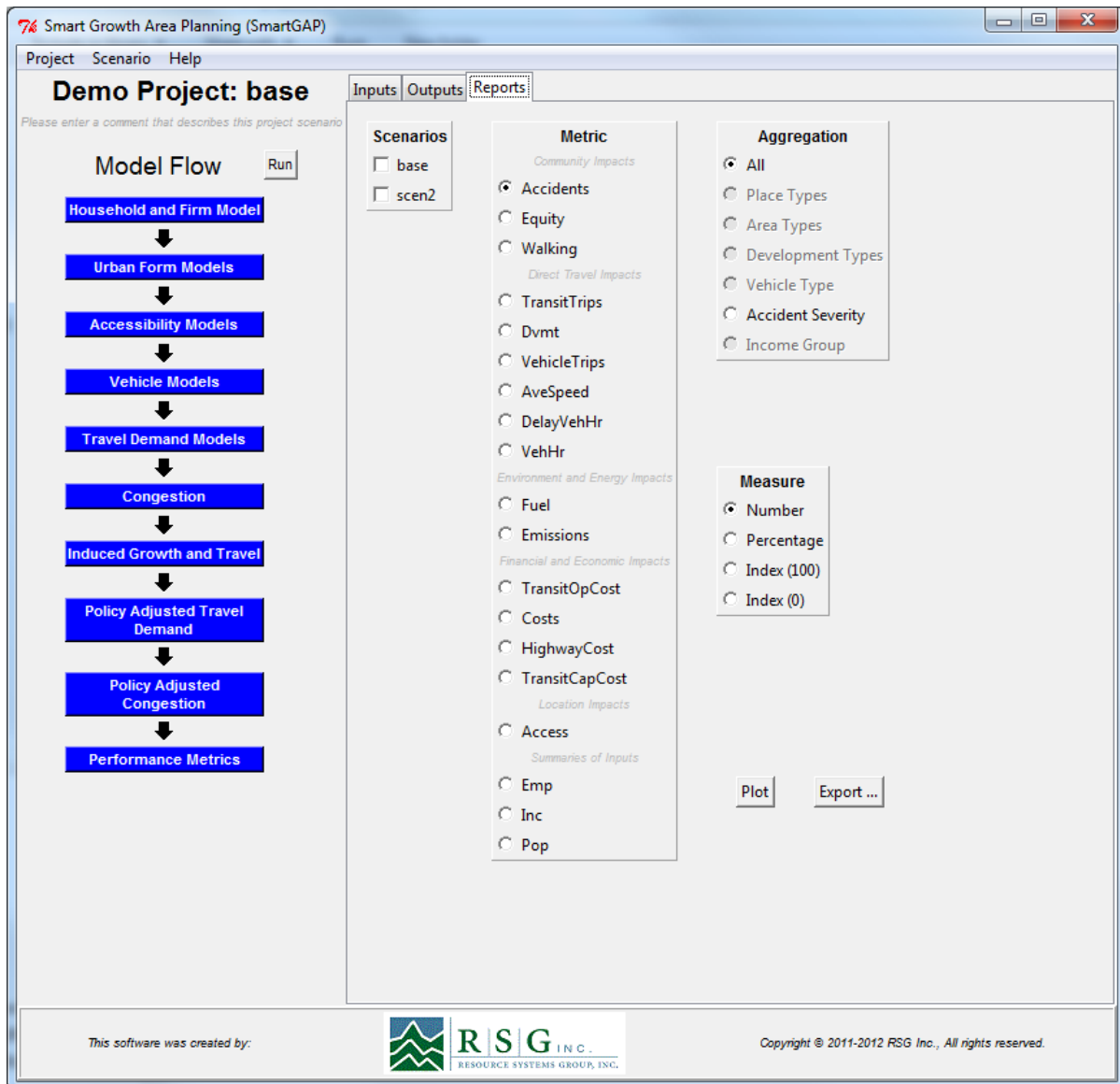


Figure 4-30: The reports tab with two scenarios run

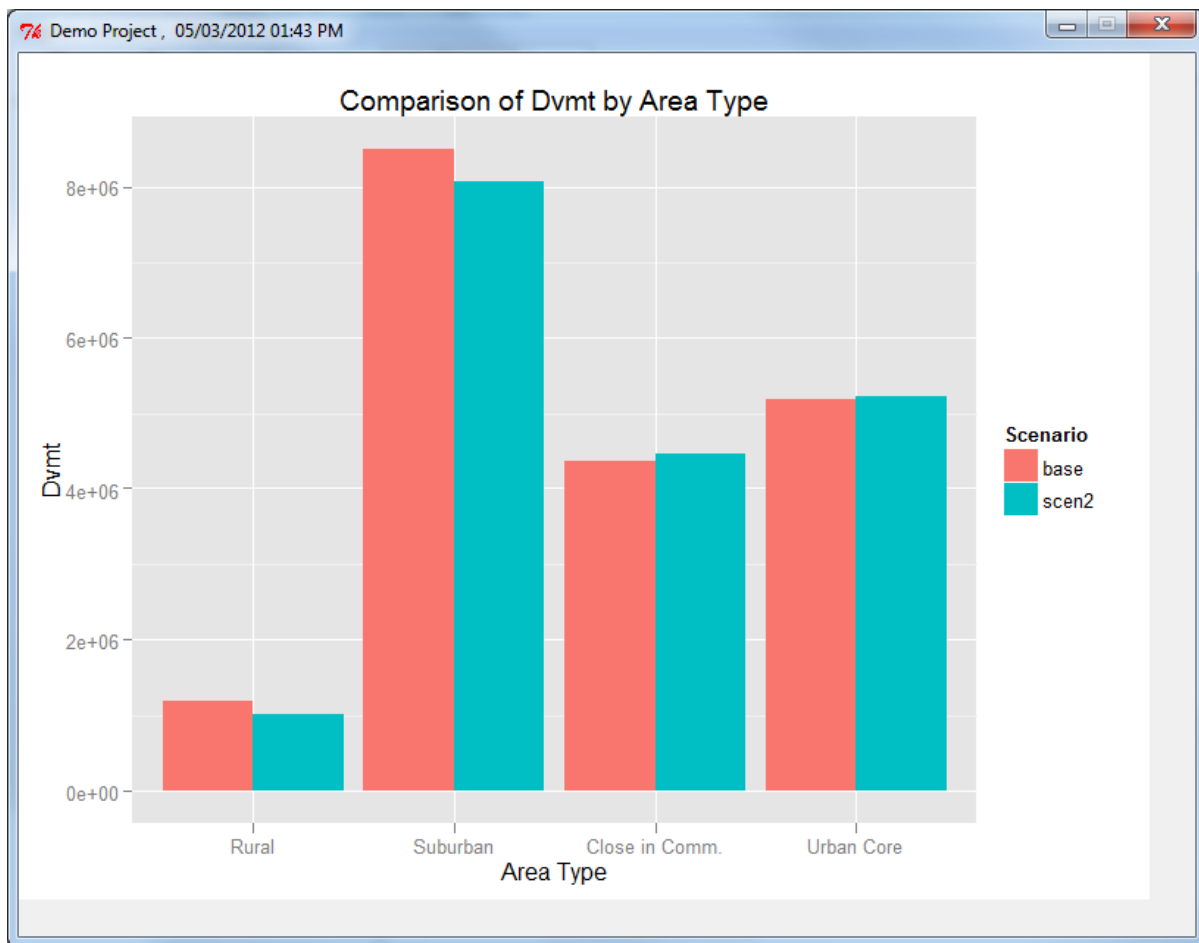


Figure 4-31: Example chart comparing Dvmt by area type for two scenarios

## CHAPTER 5. DEVELOPING INPUT DATA

Input data files are built primarily from national sources and can be modified based on regional data sources. Policy inputs are provided by the user for a particular scenario. All input data sources are assumed to be for a particular year of interest i.e. either a base year or a forecast year. The input data are tabular text files with a comma separated value (CSV) format. The CSV files include a header record on the first line, describing the variables in the files.

### Built Environment

#### *Population and Jobs by Place Type (Place\_type\_existing.csv)*

This file contains the distribution of existing (i.e. for the base year) population and employment amongst the 13 place types. Each column must sum to 1. It is acceptable to have no land use (i.e. a value of 0) in certain categories. The file format is shown in Table 5-1.

*Table 5-1: File format for Place\_type\_existing.csv*

PlaceType	PopGrowth	EmpGrowth
Rur	0.05	0.1
Sub R	0.05	0
Sub E	0.05	0.1
Sub M	0.05	0.1
Sub T	0.1	0.1
CIC R	0.1	0
CIC E	0.1	0.1
CIC M	0.1	0.1
CIC T	0.1	0.1
UC R	0.05	0
UC E	0.05	0.1
UC MU	0.1	0.1
UC T	0.1	0.1

The built environment is described by 13 place types as shown in Table 5-2. One emerging school of thought in land use planning is to consider land uses in terms of place types instead of simply residential or commercial or high density compared to low density. A place type refers to all of the characteristics of a developed area including the types of uses included, the mix of uses, the density and intensity of uses.

*Table 5-2: Place Types*

	Urban Core	Close in Community	Suburban	Rural
<b>Residential</b>	✓	✓	✓	
<b>Commercial</b>	✓	✓	✓	
<b>Mixed-Use</b>	✓	✓	✓	
<b>Transit Oriented Development</b>	✓	✓	✓	
<b>Rural/Greenfield</b>				✓

An initial typology or system to organize place types can be traced to the Smart Growth Transect, which contained six zones in its original configuration including:

- Rural Preserve
- Rural Reserve
- Edge
- General
- Center
- Core

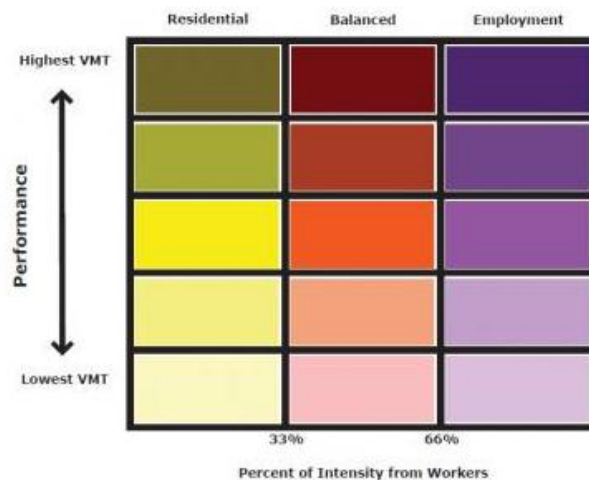
This approach to classifying place types was further refined in the Caltrans Smart Mobility which defined the following seven place types including:

- Urban Centers
- Close-In Compact Communities
- Compact Communities
- Suburban Communities
- Rural and Agricultural Lands
- Protected Lands
- Special Use Areas

Several of these place type Categories provided additional options such as the Close-In Compact Communities which had three sub-definitions including Close-In-Centers, Close-In Corridors, and Close-In Neighborhoods.

An alternative view of place types was provided by Reconnecting America, which developed a performance based place type approach for describing areas proximate to transit

stations. Station areas would vary in terms of their relative focus between residential units, employees or a mix of the two. Station areas are also characterized on their relative intensity as well as shown in Figure 5-1.



*Figure 5-1: Performance Based Typology for Transit Station Areas*

*Source: Center for Transit-Oriented Development, 2010*

The approach employed for the place types in this study is therefore an amalgam of all of these approaches, in that the terminology is borrowed from the Smart Growth Transect and Caltrans Smart Mobility Study, while the relative performance of each place type is taken from the Reconnecting America approach but applied to a region instead of transit station sites.

Four general place types were then defined including:

- The **Urban Core** was determined to be high-density mixed use places with high jobs-housing ratios, well connected streets and high levels of pedestrian activities. It is anticipated that for many regions, the Urban Core will be the traditional downtown area of which they likely would be only one. One a Statewide level, the Urban Cores would be the downtown areas of the major cities, of which there would be a limited number.
- The **Close in Community** would be those areas located near to the Urban Cores and would consist primarily of housing with scattered mixed-use centers and arterial corridors. Housing would be varied in terms of density and type. Transit would be available with a primary focus on commute trips. These areas may be classified by their residents as suburban would be considered to be Close In Communities given their adjacency to the Downtown and therefore the higher levels of regional accessibility.
- The **Suburban** place type is anticipated to represent the majority of development within regions. These communities are characterized by low level of integration of housing with jobs, retail, and services, poorly connected street networks, low levels of transit service, large amounts of surface parking, and limited walk ability.

- The **Rural** place type is defined as settlements of widely spaced towns separated by farms, vineyards, orchards, or grazing lands. These areas would be characterized by widely dispersed residential uses, little or no transit service, and very limited pedestrian facilities.

Further definition of the place types is allowed through the use of sub-categories within the Urban Core, Close in Community, and Suburban place types including:

- **Residential** includes all place types that are predominantly residential in character with limited employment and retail opportunities. Examples of this sub-category might include typical Suburban Residential or areas of the Downtown which are primarily residential as well. It is anticipated that this sub-category may be found in all of the place types except for rural.
- **Employment** includes those areas which are focused on employment with limited retail and residential. An example of this might include a Suburban Office Complex or a large cluster of office buildings within a Close In Community or Urban Core. As with the residential sub-category, it is anticipated that this type of use would be found in all place types except for rural.
- **Mixed-Use** are those areas within a region which have a mix of residential, employment, and retail uses. While this sub-category can be found in the Suburban place type, it is most commonly found in the Close in Community and Urban Core place type. Downtown areas that have retained their residential population to complement the employment are examples of this sub-category.
- **Transit Oriented Development (TOD)** which is similar to the other sub-categories, but applied to all place types except for Rural areas since it is thought to be highly unlikely that a rural TOD would be developed. The TOD sub-category is characterized by greater access to transit in all place types. Examples of this sub-category might include a Suburban TOD focused on a commuter rail station.

The process of allocating existing land use to the thirteen place types is somewhat dependent on the types of data available in a region that describe existing land use, and the process can be either very detailed or somewhat simplified. The following description relays the process developed by Atlanta Regional Commission (ARC) as part of the pilot testing of SmartGAP and provides an example of how, mechanically, an agency can approach this allocation. It should be noted that this is merely one approach and not a specific recommendation for a method that should be followed.

In general, ARC followed a somewhat detailed process to derive input data from land use data as presented in their “Unified Growth Policy Map”, and from their regional travel demand model. They developed heuristics to align their land use with the 13 place types that SmartGAP uses.

The conversion of land use data to the place type scheme used in SmartGAP involved taking ARC’s Unified Growth Policy Map (UGPM) Areas and converting them to the 13 SmartGAP place types.

1. The first step was to allocate the UGPM areas to the four area types used in SmartGAP. The Urban Core area type includes Region Core, Region Employment Centers and Aerotropolis UGPM areas; Close in Community includes Maturing Neighborhoods; Suburban includes Developing Suburbs and Established Suburbs; and Rural includes Rural Areas and Developing Rural.
2. The ARC traffic analysis zone (TAZ) system was overlaid with the area types and the centroid of the TAZ was used to determine its area type.
3. The SmartGAP development type, the other dimension of the place type matrix, which included residential, mixed-use, employment, and TOD development types was determined for each TAZ using the base year percentage of the TAZ's employment in relation to the total of the population and employment in the TAZ. The mix between the employment and employment was used to determine the TAZs development type using the following cut points:
  - Residential: < 33.33%
  - Mixed Use: 33.33 to 66.67%
  - Employment: > 66.67%
4. Only one TAZ was determined to be TOD as a development type, Lindbergh Center, in the Urban Core area type.
5. The combination of the area type and the development type was then used to allocate all TAZs to one of the 13 place types.
6. The 2010 TAZ employment and population totals were summed by the 13 place type and then scaled to total one for both employment and population as called for by the file format for place\_type\_existing.csv.

The population and employment growth amounts between 2010 and 2040 were determined for the 13 place types and were scaled to total 1 for both employment and population as called for by the file format for place\_type\_growth.csv.

## **Demand**

### *Auto and Transit Trips per Capita (trips\_per\_cap.csv)*

This file contains regional averages for auto and transit trips per day for the base year. The file format is shown in Table 5-3.

- **Auto** – is the regional average of auto trips per capita, including drive alone and shared ride travel. This data can be derived from the National Household Travel Survey (<http://nhts.ornl.gov/index.shtml>) by region or from a local household travel survey or regional travel demand forecasting model.
- **Transit** - is the regional average of transit trips per capita, including walk and drive access to transit. This data can be derived from the National Transit Database.

<http://www.ntdprogram.gov/ntdprogram/data.htm>), where the annual database contains a “service” table that has annual transit trip data for each transit operator or from a local household travel survey or regional travel demand forecasting model.

*Table 5-3: File format for trips\_per\_cap.csv*

Mode	Trips
Auto	3.2
Transit	0.4

*Base Daily Vehicle Miles Traveled (base\_vmt.csv)*

This file contains information on total light vehicle VMT and the split by functional class for light vehicles for the base year. The file format is shown in Table 5-4.

- **LtVehDvmt** – is light vehicle daily VMT in unit of thousands of miles
- **FwyArtProp** – is the proportions of daily VMT for light vehicles that takes place on freeways and arterials (i.e. the remainder of VMT takes place on lower functional class roads.

These data can be derived from a combination of Highway Performance Monitoring System (<http://www.fhwa.dot.gov/policyinformation/hpms.cfm>) data, Federal Highway Cost Allocation Study data, and regional data. Light vehicle daily VMT can be estimated by subtracting truck and bus VMT from total VMT provided in the HPMS. The proportions of light vehicle daily VMT on freeways and arterials can be derived from the HPMS data.

*Table 5-4: File format for base\_vmt.csv*

Area	LtVehDvmt	FwyArtProp
Metro	27244	0.77

*Employment (Existing) (employment.csv)*

This file contains employment data for each of the counties that make up the region. The file format is shown in Table 5-5. The file is derived from County Business Pattern (CBP) data by county (see <http://www.census.gov/econ/cbp/> for more information on this dataset). Industries are categorized by the North American Industrial Classification System (NAICS) 6 digit codes. Firm size categories are:

- 1- 4 employees
- 5-9 employees
- 10-19 employees
- 20-99 employees
- 100-249 employees
- 250-499 employees



- 500-999 employees
- 1,000-2,499 employees
- 2,500-4,999 employees
- Over 5,000 employees

A database of preprocessed CBP data is provided with SmartGAP, but users can also format their own local data into the file format. While the county field is required to be present, the business synthesis process does not require a meaningful value and therefore users may simply enter “region”. It is also not necessary to use such detailed NAICS categories if those are not available; the current business synthesis model and subsequent models to not use this level of detail (although future versions of the model may) – at minimum, the number of establishments for all employment types can be provided by size category. Regions with significant employment in industries such as government and public administration that are not covered by the CBP may need to add records that to the file that cover this type of employment to more accurately match employment totals in their region.

*Table 5-5: File format for employment.csv (partial file shown)*

county	year	naics	emp	est	n1_4	n5_9	n10_19	n20_49	n50_99	n100_249	n250_499	n500_999	n1000	n1000_1	n1000_2	n1000_3	n1000_4
Multnomah	2005	113110	0	5	2	1	0	2	0	0	0	0	0	0	0	0	0
Multnomah	2005	113310	0	3	2	0	0	1	0	0	0	0	0	0	0	0	0
Multnomah	2005	114111	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
Multnomah	2005	114112	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Multnomah	2005	115114	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0
Multnomah	2005	115210	0	4	3	1	0	0	0	0	0	0	0	0	0	0	0
Multnomah	2005	115310	0	5	2	0	1	1	1	0	0	0	0	0	0	0	0
Multnomah	2005	212319	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Multnomah	2005	212321	0	4	1	1	1	1	0	0	0	0	0	0	0	0	0
Multnomah	2005	212322	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Multnomah	2005	213112	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Multnomah	2005	213115	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
Multnomah	2005	221112	0	2	1	0	0	1	0	0	0	0	0	0	0	0	0
Multnomah	2005	221119	0	2	0	0	0	1	0	0	1	0	0	0	0	0	0

#### *Employment (Growth) (employment\_growth.csv)*

This file contains a growth rate for employment in the region between the base year and the future year. A rate of 1 indicates no changes in overall employment, a value of more than 1 indicates some growth (e.g. 1.5 = 50% growth) and a value of less than 1 indicates decline in employment. The file format is shown in Table 5-6.

*Table 5-6: File format for employment\_growth.csv*

key	value
EmploymentGrowth	1.5

#### *Population (Existing and Growth) (pop\_by\_age.csv)*

This file contains population estimates/forecasts by county and age cohort for each of the base and future years. The file format is shown in Table 5-7, which shows the six age categories used by the population synthesis model: 0 to 14, 15 to 19, 20 to 29, 30 to 54, 55 to 64 and 65 plus. Base year data are derived from Census data: a database of preprocessed population data by county and age group for 1990 – 2010 is provided with SmartGAP. Future year data must be

developed by user; in many regions population forecasts are available from regional or state agencies and/or local academic sources. As the employment data, the future data need not be county specific but rather regional totals by age group can be entered into the file with a value such as “region” entered in the county field.

*Table 5-7: File format for pop\_by\_age.csv*

County	Year	Age0to14	Age15to19	Age20to29	Age30to54	Age55to64	Age65Plus
Multnomah	2005	129869	41133	99664	277854	71658	72648
Multnomah	2035	169200	48800	144050	327750	116100	162800

*Regional Income (regional\_income.csv)*

This file contains information on regional average per capita income by forecast year in year 2000 dollars. The file format is shown in Table 5-8. The data can be obtained from the U.S. Department of Commerce Bureau of Economic Analysis

(<http://www.bea.gov/regional/index.htm>) for the current year or from regional or state sources for forecast years.

*Table 5-8: File format for regional\_income.csv*

Year	Income
2005	32515
2035	40000

*Truck and Bus Vehicle Miles Traveled (truck\_bus\_vmt.csv)*

This file is a table showing the proportion of VMT by truck and also the proportion of truck and bus daily VMT by functional class (freeway, arterial, other). The file format is shown in Table 5-9, with one row for Bus VMT data and one row for Truck VMT data. It should be noted that it is not necessary to enter a values in the PropVMT column for BusVmt as this is calculated using the values in the transportation\_supply.csv input file.

The truck VMT proportion (PropVMT column, TruckVMT row) can be obtained from Highway Performance Monitoring System (<http://www.fhwa.dot.gov/policyinformation/hpms.cfm>) data and local sources or the regional travel demand model if one exists.

The proportions of VMT by functional class can be derived from the Federal Highway Cost Allocation Study and data from transit operators. The Federal Highway Cost Allocation Study (Table II-6, 1997 Federal Highway Cost Allocation Study Final Report, Chapter II, <http://www.fhwa.dot.gov/policy/hcas/final/two.htm>) is used to calculate the average proportion of truck VMT by functional class. Data from transit authorities are used to calculate the proportions of bus VMT by urban area functional class.

Table 5-9: File format for truck\_bus\_vmt.csv

Value	PropVmt	Fwy	Art	Other
BusVmt	0	0.15	0.591853844	0.258146156
TruckVmt	0.08	0.452028197	0.398645294	0.149326508

## Transport Supply

### Road Lane Miles and Transit Revenue Miles (transportation\_supply.csv)

This file contains the amount of transportation supply in the base year in terms of lane miles of freeways and arterial roadways and the revenue miles operating by the transit system in the region. The file format is shown in Table 5-10.

- **Freeway** and **Arterial** are total lane miles for those functional classes in the region. These data can be derived FHWA's Highway Statistics data.  
([http://www.fhwa.dot.gov/policy/ohim/hs05/roadway\\_extent.htm](http://www.fhwa.dot.gov/policy/ohim/hs05/roadway_extent.htm))
- **Bus** and **Rail** are annual bus and rail revenue miles per capita for the region. These data can be derived from the National Transit Database.  
(<http://www.ntdprogram.gov/ntdprogram/data.htm>), where the annual database contains a "service" table that has annual revenue mile data by mode for each transit operator.

Table 5-10: File format for transportation\_supply.csv

SupplyClass	Miles
Freeway	250
Arterial	900
Bus	19
Rail	4

## Policy

The policies that can be tested using SmartGAP are described in detail in Chapter 3 of the SHRP 2 C16 Final Report. The input files that allow assumptions around each of these policies to be defined are described below.

### % Growth by Place Type (place\_type\_growth.csv)

This file is a table of the percent growth for each of the 13 place types. The file format is shown in Table 5-11.

Table 5-11: File format for place\_type\_growth.csv

PlaceType	PopGrowth	EmpGrowth
Rur	0.05	0
Sub R	0.05	0
Sub E	0.05	0
Sub M	0.05	0
Sub T	0.1	0
CIC R	0.1	0
CIC E	0.1	0
CIC M	0.1	0
CIC T	0.1	0
UC R	0.05	0.25
UC E	0.05	0.25
UC MU	0.1	0.25
UC T	0.1	0.25

*% Increase in Auto Operating Cost (auto\_op\_cost\_growth.csv)*

This file is a single value of the percent increase in auto operating cost in cents per mile. This can be used to test different assumptions for future gas prices or the effects of increased gas taxes. The file format is shown in Table 5-12.

Table 5-12: File format for auto\_op\_cost\_growth.csv

key	value
OpCostGrowth	1.5

*% Increase in Road Lane Miles, Transit Revenue Miles per Cap.  
(transportation\_supply\_growth.csv)*

This file contains the four values that allow the user to change the transportation supply in the region in the future year. The file format is shown in Table 5-13.

- **Freeway** –is the percent increase in road lane miles including freeways, arterials and other facilities. By default, the transportation supply is assumed to grow in line with population increase; therefore a value of 1 indicates growth in proportion with population growth. A value less than 1 indicates that there will less freeway lane mile supply per person in future while a value of 1 indicates faster freeway expansion than population growth.
- **Arterial** is a similar value to freeway except that it measures arterial lane mile growth. It is also proportional to population growth,
- **Bus** – is the percent increase in transit revenue miles per capita for bus. It behaves in a similar way to the freeway and rail values in that a value of 1 indicates per capita revenue miles stays constant.

- **Rail** - is the percent increase in transit revenue miles per capita for rail. This encompasses all rail modes, from light rail through to commuter rail.

*Table 5-13: File format for transportation\_supply\_growth.csv*

SupplyClass	Growth
Freeway	1.1
Arterial	1
Bus	1.2
Rail	1.1

*% of Employees Offered Commute Options (commute\_options.csv)*

This file contains assumptions about the availability and participation in work based travel demand management programs. The policies are ridesharing programs, transit pass programs, telecommuting or alternative work schedule programs, and vanpool programs. For each the user enters the proportion of workers who participate (the data items with the “Participation” suffix). For one program, the transit subsidy, the user must also enter the subsidy level in dollars for the TransitSubsidyLevel data item. The file format is shown in Table 5-14.

*Table 5-14: File format for commute\_options.csv*

TDMProgram	DataItem	DataValue
Ridesharing	RidesharingParticipation	0.05
TransitSubsidy	TransitSubsidyParticipation	0.1
TransitSubsidy	TransitSubsidyLevel	1.25
WorkSchedule	Schedule980Participation	0.01
WorkSchedule	Schedule440Participation	0.04
WorkSchedule	Telecommute1.5DaysParticipation	0.13
Vanpooling	LowLevelParticipation	0.04
Vanpooling	MediumLevelParticipation	0.01
Vanpooling	HighLevelParticipation	0.01

*% Road Miles with ITS Treatment (its.csv)*

This file is an estimate of the proportion of road miles that have improvements which reduce incidents through ITS treatments in both the base and future years. The file format is shown in Table 5-15, and values entered should be between 0 and 1, with 1 indicating that 100% of road miles are treated.

*Table 5-15: File format for its.csv*

Year	ITS
2005	0
2035	0

*Auto Operating Surcharge per VMT (vmt\_charge.csv)*

This file contains is a cost in cents per mile that would be levied on auto users through the form of a VMT charge. The file format is shown in Table 5-16.

*Table 5-16: File format for vmt\_charge.csv*

key	value
VmtCost	0.05

*Bicycling/Light Vehicle Targets (light\_vehicles.csv)*

This file contains input data for the non-motorized vehicle model. In SmartGAP, non-motorized vehicles are bicycles, and also electric bicycles, Segways, and similar vehicles that are small, light-weight and can travel at bicycle speeds or slightly higher. The file format is shown in Table 5-17. The parameters are as follows:

- TargetProp – non-motorized vehicle ownership rate (average ratio of non-motorized vehicles to driver age population)
- Threshold – SOV tour mileage threshold used in the SOV travel proportion model. This is the upper limit for tour lengths that are suitable for reallocation to non-motorized modes.
- PropSuitable – proportion of SOV travel suitable for non-motorized vehicle travel.

*Table 5-17: File format for light\_vehicles.csv*

DataItem	DataValue
TargetProp	0.2
Threshold	2
PropSuitable	0.1

*Increase in Parking Cost and Supply (parking\_growth.csv)*

This file contains information that allows the effects of policies such as workplace parking charges and “cash-out buy-back” programs to be tested. The file format is shown in Table 5-18. The input parameters are as follows and should be entered for both the base and future year:

- PropWrkPkg – proportion of employees that park at work
- PropWrkChrgd – proportion of employers that charge for parking
- PropCashOut – proportion of employment parking that is converted from being free to pay under a “cash-out buy-back” type of program
- PrkOthChrgd – proportion of other parking that is not free
- PkgCost – average daily parking cost.

*Table 5-18: File format for parking\_growth.csv*

Year	PropWrkPkg	PropWrkChrgd	PropCashOut	PropOthChrgd	PkgCost
2005	1	0.1	0	0.05	5
2035	1	0.1	0	0.05	5

## CHAPTER 6. PERFORMANCE METRICS

The performance metrics, reported in SmartGAP's output data files, are designed to address a variety of impacts that are helpful for decision-making. The output data are saved as .RData files and can be exported as tabular text files with a comma separated value (CSV) format. The CSV files include a header record on the first line, describing the variables in the files. The performance metrics can all be charted using the reporting tab in SmartGAP, which includes the ability to compare the results across scenarios.

### Direct Travel Impacts

#### *Daily Vehicle Miles Traveled*

Daily vehicle miles traveled is calculated by the travel demand models with scenario changes that reflect the effects of changes in land use, transportation supply, and policies. The model reports light vehicle VMT for each place type. (Additional output files not reported in SmartGAP's user interface contain VMT for light vehicles, trucks and buses and are used in the estimation of congestion effects).

#### *Daily Vehicle Trips*

The model's calculations generally work with VMT and not individual trips. The change in the number of vehicle trips is calculated using a set of elasticities from Index 4D Values (2001) shown in Table 6-1 that pivots from the current number of vehicle trips per capita based on the scenario's allocation of growth by place type. The elasticities shown in the table are applied to D values, which are proportional values for each place type that are relative to a regional average for that D value that is set to 1.0. The model reports the additional number of trips caused by the growth assumed in the scenario and not the regional total.

*Table 6-1: Vehicle Trip Elasticities*

D	Description	Vehicle Trip Decrease
Density	Household/Population Density	-0.043
Diversity	Land Use Mix (entropy)	-0.051
Design	Intersection/Street Density	-0.031
Regional Accessibility	Job Accessiblity By Auto	-0.036
Distance to Transit	Distance to Nearest Transit Stop	0

#### *Daily Transit Trips*

The change in the number of transit trips is calculated using a set of elasticities from Index 4D Values (2001) shown in Table 6-2 that pivots from the current number of transit trips



per capita based on the scenario's allocation of growth by place type. The elasticities shown in the table are applied to D values, which are proportional values for each place type that are relative to a regional average for that D value that is set to 1.0. The model reports the additional number of trips caused by the growth assumed in the scenario and not the regional total.

*Table 6-2: Transit Trip Elasticities*

D	Description	Transit Trip Increase
Density	Household/Population Density	0.07
Diversity	Land Use Mix (entropy)	0.12
Design	Intersection/Street Density	0.23
Regional Accessibility	Job Accessibility By Auto	0
Distance to Transit	Distance to Nearest Transit Stop	0.29

#### *Average Travel Speeds by Vehicle Type*

The congestion component of the model is used to produce both travel speeds by vehicle type and the vehicle hours of travel and delay. VMT for each of light vehicles, heavy trucks, and buses, is assigned to speeds bins for the three facility types that the model considers – freeways, arterials and other roads. Speed distributions, in terms of the amount of VMT that occurs within each speed bin, are used to derive average speeds

#### *Vehicle Hours of Travel, Delay*

The congestion model calculates vehicles hours of travel using the VMT by speed distributions discussed above. The amount of delay is calculated by comparing the vehicle hours of travel with the amount of vehicle hours of travel that would have taken place if travel was at free flow speeds.

### **Environment and Energy Impacts**

#### *Fuel Consumption*

Fuel consumption (in gasoline equivalent gallons) by vehicle type is calculated from the respective estimates of VMT and fuel economy. These estimates are then split into fuel types. The model addresses five fuel types: gasoline, ultra-low-sulfur diesel (ULSD), ethanol, biodiesel, and CNG. For each vehicle type, input data specify the fuel proportions by year. These data can be changed for future year scenarios via the parameters menu) to represent various fuels policies and assumptions.

For light vehicles (automobiles and light trucks), the first step is to allocate fuel consumed between gasoline, CNG, and diesel types. Different proportions are provided for

automobiles and light trucks. Fuel for gasoline engines is then split between gasoline, ethanol, and CNG based on input proportions. Similarly, diesel fuel use is split between ULSD and biodiesel. A similar process is used to split heavy truck and bus fuel consumption into fuel types. The report of fuel consumption by place type in SmartGAP reports just light vehicle fuel consumption.

### *Greenhouse Gas Emissions*

Once fuel consumption is split into the five types (measured in gasoline equivalent gallons), CO<sub>2</sub> equivalents of emissions can be calculated in a straightforward manner. The energy value of the fuel consumed by type is calculated by multiplying by the energy value of a gallon of gasoline. Then the CO<sub>2</sub> equivalent (CO<sub>2</sub>e) emissions are calculated by applying the appropriate carbon intensities (grams CO<sub>2</sub>e per mega joule) of each fuel type. Values reflect “pump-to-wheels” emission rates, representing just the tailpipe emissions and do not include the “well-to-pump” emissions resulting from the production and transportation of fuels. Table 6-3 shows the values included as parameters in the model. The values are derived from the MOVES 2010a database (the fuel sub type table provides carbon contents and oxidation factors) and from Emission Facts: Greenhouse Gas Emissions from a Typical Passenger Vehicle (U.S. EPA, 2011) to convert to CO<sub>2</sub> equivalents (which includes the global warming potential of other gases emitted by vehicles such as CH<sub>4</sub>, N<sub>2</sub>O, and HFCs).

*Table 6-3: Carbon Intensity by Fuel Type (Grams CO<sub>2</sub>e Per Mega Joule)*

Fuel Type	Carbon Intensity (gm per mega joule)
Ultra-low sulfur diesel (USLD)	77.19
Biodiesel	76.81
Reformulated gasoline (RFG)	75.65
CARBOB (gasoline formulated to be blended with ethanol)	75.65
Ethanol	74.88
Compressed natural gas (CNG)	62.14

All of the light vehicle calculations of fuels and emissions are done at the disaggregate level of households. This allows emissions to be aggregated to place type and along other dimensions. The report of greenhouse gas emissions by place type in SmartGAP reports just light vehicle fuel consumption. Heavy truck and transit emissions are calculated at the regional level.

## **Financial and Economic Impacts**

### *Regional Highway Infrastructure Costs*

The source for highway infrastructure costs is FHWA’s Highway Economic Requirements System model, or HERS. Information was obtained from Chapter 6 of the 2005 Technical Report for all US states (FHWA, 2005). Table 8-1 in HERS provides unit costs (per lane mile) for both Rural and Urban highway systems, and distinguishes among three functional classes: interstates, freeways and expressways; other principal arterials; and minor arterials and collectors. Costs estimates are provided for the following improvements:

- Reconstruction and widening
- Reconstruct pavement
- Resurface and widen lanes
- Resurface pavement
- Improve shoulders

Additional choices are offered to distinguish between adding a lane at “normal” vs. “high cost”, and also for pavement realignment, also under normal vs. high cost conditions.

For practical reasons, it was decided to use only “new construction” (which also includes adding lanes) costs as the basis for the cost estimates, and to ignore for now the categories of reconstruction, resurfacing, and realignment, although the normal vs. high estimates are used to provide a range for users. These construction costs include right of way, construction, and a “small” allowance for bridges and support facilities.

The infrastructure costs focus only on the “urban” system, not rural, which also makes it possible to differentiate by three size classes: Small Urban, Small Urbanized, and Large Urbanized. The numbers in Table 6-4 are in 2002 dollars; FHWA advises escalation to current dollars using its National Highway Construction Cost Index (NHCCI, which is available online at <http://www.fhwa.dot.gov/policyinformation/nhcci.cfm>); the report in SmartGAP escalates uses this Index to escalate to 2010 values.

*Table 6-4. Construction Cost per Lane Mile in 2002 Dollars*

Functional Classification	Small Urban	Small Urbanized	Large Urbanized
Freeways	\$3.1 - \$11.1	\$3.4 - \$12.1	\$5.7 - \$60.0
Principal Arterial	\$2.6 - \$9.4	\$2.9 - \$10.2	\$4.2 - \$15.0
Minor Arterial/ Collector	\$2.0 - \$7.0	\$2.1 - \$7.4	\$2.9 - \$10.2

HERS includes a table of state cost indices if desired, although a spokesperson for HERS says that the general sentiment has been toward not using them for reliability reasons.

#### *Regional Transit Infrastructure and Operating Costs*

The source for transit capital and operating costs is the National Transit Database (NTD, which is available online at <http://www.ntdprogram.gov/ntdprogram/>), and in particular the National Transit Profile which is available on the NTDB website. The most recent statistics published are for 2009, so CPI adjustments may be necessary if more current data are not available to the user at the time. Costs are available in a variety of index formats, e.g., cost per revenue mile or hour, though cost per passenger trip appears to be the most relevant association with estimation of future transit service needs. These costs are presented in Table 6-5.

*Table 6-5. Net Cost to Supply an Unlinked Passenger Trip by Transit Mode (2009)*

Mode	Capital Cost	Operating Cost	Total Cost	Fare Revenue	Net Cost
Bus	\$0.71	\$3.40	\$4.11	\$0.91	\$3.20
Heavy Rail	\$1.78	\$1.80	\$3.58	\$1.09	\$2.49
Commuter Rail	\$5.74	\$9.80	\$15.54	\$4.69	\$10.85
Light Rail	\$7.82	\$3.00	\$10.82	\$0.78	\$10.04

Costs are presented for each mode, since the capital, operating and revenue profiles are quite different for each. It is interesting to note that the comparative cost per trip of bus and heavy rail, while commuter rail and light rail are both considerably -- almost four times -- higher.

#### *Annual Traveler Cost (Fuel + Charges)*

The traveler costs values reported by SmartGAP are the total of the following components:

1. Gas cost: the fuel consumption multiplied by the gas cost parameter
2. Fuel tax: the fuel consumption multiplied by the fuel tax parameter
3. Parking costs: the parking costs paid under the travel demand management policies in effect for the scenario
4. VMT charge: VMT multiplied by the VMT charge in effect for the scenario

The values reported are annual costs by place type and account for light vehicle travelers only.

## **Location Impacts**

### *Regional Accessibility*

The performance measure for land market and location impacts is related to the regional accessibility calculations, embodied in the analysis of place types. The estimation of VMT by place types includes one variable related to regional accessibility which is jobs accessibility by auto. Job accessibility by auto would be highest in the urban core area and relatively lower in the other place types. The lowest job accessibility by auto would occur in the rural place types.

It is anticipated that the job accessibility by auto would vary based on the amount of new growth allocated to the various place types. If a majority of the new growth is allocated to the rural and suburban place types, it is anticipated that there would be limited growth in jobs

accessibility by auto. Otherwise, if a majority of the new growth is allocated to the close in community and urban core place types, then there will be more growth in this measure.

SmartGAP reports the relative increase in jobs accessibility in auto based on the existing scenario. This relative increase is a function of the distribution of growth between the four place types, weighted by the population and employment growth in each of the place types.

## Community Impacts

### *Accident Rates*

Road safety impacts are calculated by factoring the amount of VMT. Daily VMT is converted to annual VMT and then to units of 100 million miles traveled. The following national average rates, from the Fatality Analysis Reporting System General Estimates System (2009) by US Department of Transportation, are then applied to calculate the number of fatal and injury accidents and the value of property damage:

- Fatal: 1.14 per 100 Million Miles Traveled
- Injury: 51.35 per 100 Million Miles Traveled
- Property damage: 133.95 per 100 Million Miles Traveled

### *Walking Percentage Increase*

The percentage change in the amount of walking is calculated by applying a set of elasticities developed in their 4D Meta Analysis by Cervero and Ewing (Table 6-6). The elasticities shown in the table are applied to D values, which are proportional values for each place type that are relative to a regional average for that D value that is set to 1.0. The product of the elasticity and D value is applied to the place type growth quantities for the scenario to calculate the percentage increase or decrease in walking for new residents in the region relative to the current place type distribution.

*Table 6-6: Walking Elasticities*

D	Description	Walking Increase
Density	Household/Population Density	0.07
Diversity	Land Use Mix (entropy)	0.15
Design	Intersection/Street Density	0.39
Regional Accessibility	Job Accessibility By Auto	0
Distance to Transit	Distance to Nearest Transit Stop	0.15

### *Job Accessibility by Income Group*

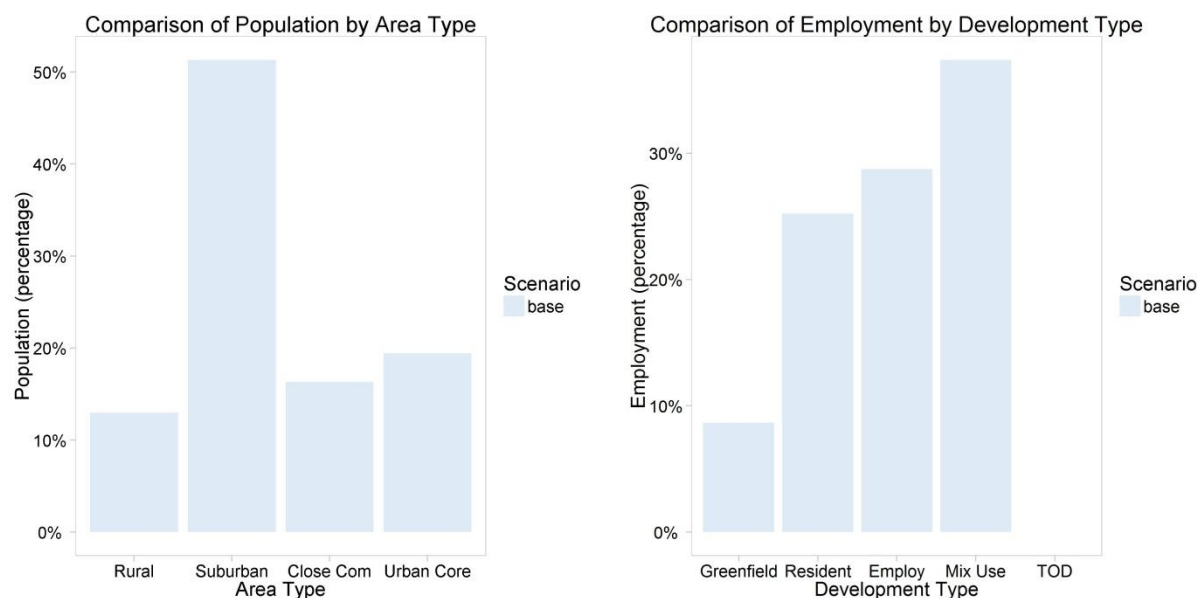
This is an income stratification of the regional accessibility measure.

## CHAPTER 7. SMARTGAP APPLICATION EXAMPLES

This section of the user's guide provides some examples from the pilot testing of SmartGAP on how a set of scenarios might be developed, tested, and analyzed by an agency. Chapter 4 of the SHRP 2 C16 Final Report provides a more complete discussion of the pilot testing process.

### Developing the base scenario

Chapter 5 discusses the development of the input files, many of which are involved in describing the base scenario. The most complex input to develop is likely to be the land use allocation to place types. The section on built environment inputs in Chapter 5 includes the approach used by ARC during their pilot test of SmartGAP and provides a good example of how to achieve the allocation to place types. TRPC followed a similar GIS based procedure to that followed by ARC, while MDOT followed a simpler, qualitative process. The reporting tab can be used to produce charts of several of the land use and demographic inputs for the base scenario to review how the results of the allocation process (Figure 7-1).



*Figure 7-1: Examples of population allocation by area type (ARC pilot test) and employment allocation by development type (TRPC pilot test)*

### Designing scenarios

SmartGAP is designed to provide a flexible platform for efficient testing a variety of policies individually and in combination in a consistent framework. Once the base scenario is created, which is generally the expected future, scenarios can be added using the process in described in Chapter 4. In those new scenarios, any of the inputs can be varied from the values used in the base scenario in order to evaluate the effect of that policy change or alternative investment. Each of the pilot studies tested a relatively consistent set of eight scenarios, and an additional two scenarios are reported in the SHRP 2 C16 Final Report that were tested in

Portland by the research team. The scenarios, shown in Table 7-1, focus initially on testing changes individually to understand the impacts of those policies separately. For example, scenario #2 is the same as the baseline except for just the addition of extra transit supply. Scenarios #5-7 test the effect of increasing the magnitude of a policy: each deals only with focusing development in dense areas, with each successive scenario representing a more aggressive implementation of that policy. Scenario #8 is an example of combining several strategies across the land use, transportation and policy areas, as might be done in reality. This allows the evaluation of the combinatorial effect of those policies: in some cases, the effects from different changes might counteract each other, and in others they might have reinforcing effects.

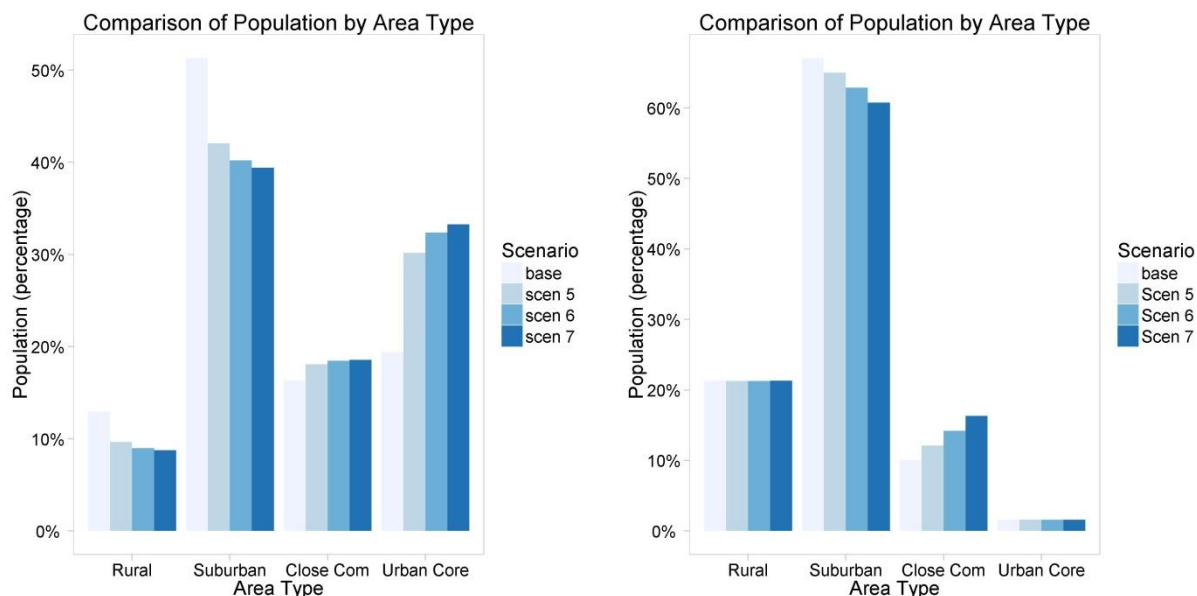
*Table 7-1: Pilot test scenario definitions*

Scenario	Land Use	Transportation	Policy
#1. Baseline	Baseline	Baseline	Baseline
#2. Increase Transit Supply	Baseline	+ 20% in Transit Supply	Baseline
#3. Increase Roadway Supply	Baseline	+ 20% in Roadway Supply	Baseline
#4. Add ITS	Baseline	Baseline	+20% in Lane Miles with ITS
#5. Shift 10% Growth to More Dense Areas	Shift 10% Pop, Emp to Close in Community, 10% to Urban Core, from Suburban Area	Baseline	Baseline
#6. Shift 20% Growth to More Dense Areas	Shift 20% Pop, Emp to Close in Community, 20% to Urban Core, from Suburban Area	Baseline	Baseline
#7. Shift 30% Growth to More Dense Areas	Shift 30% Pop, Emp to Close in Community, 30% to Urban Core, from Suburban Area	Baseline	Baseline
#8. Shift 30% Growth to More Dense Areas and Add ITS and Transit Supply	Shift 30% Pop, Emp to Close in Community, 30% to Urban Core, from Suburban Area	+20% in Transit Supply	+20% in Lane Miles with ITS
#9. Increase Operating Costs	Baseline	Baseline	+ 25% auto operating cost growth
#10. Add VMT Charge	Baseline	Baseline	10 c/mile VMT charge

During the pilot testing, the agencies implemented the scenarios based on their knowledge of their own regions. This meant applying caps in some cases to the amount of land use reallocated in scenarios #5-7, for example. The built environment inputs can be compared across scenarios in the reporting tab of SmartGAP to understand and review how the scenario definitions affect the future distribution of population and employment. Figure 7-2 compares the

approaches used by ARC and TRPC for the land use change scenarios. The charts show the focus in ARC of moving suburban to urban core development and in TRPC of more reallocation to close in communities with little growth allocated to their urban core.

*Figure 7-2: Examples of population allocation by area type (ARC pilot test to the left, TRCP pilot test to the right) for base and scenarios #5-7.*



SmartGAP has no constraint on the number of scenarios that can be tested or on the number of inputs that can be changed in a given scenario. The only constraints are the time available to develop, run and analyze the results available to the user and their ability to understand and interpret the results when multiple inputs are changed in a scenario. A recommended approach is to test individual policies at first, then move to testing combinations once the individual effects are understood. For policies where the aggressiveness of the implementation of the policy could vary significantly, multiple scenarios can be evaluated, as with scenarios #5-7 discussed above. Chapter 5 discusses the various inputs files and how they can be varied, and the SHRP 2 C16 Final Report provides additional context and references discussing the different policies. An important aspect of scenario testing to keep in mind is that testing a wide range of inputs, even beyond what might be expected to be achievable, is part of the task in order to understand what outcomes might result from a range of inputs.

### Analyzing scenario results

SmartGAP produces results in the form of performance metrics, which are described in Chapter 6. The results are available in tabular form via the outputs tab in SmartGAP, or can be displayed and exported in form of charts in the report tabs. Both the outputs tab and the reports tab are described in Chapter 4.

The reports tab allows two general types of comparison: within scenario and across scenarios. The two can be combined on a single chart (although this can become harder to interpret if many scenarios are compared). This section of the user's guide provides some



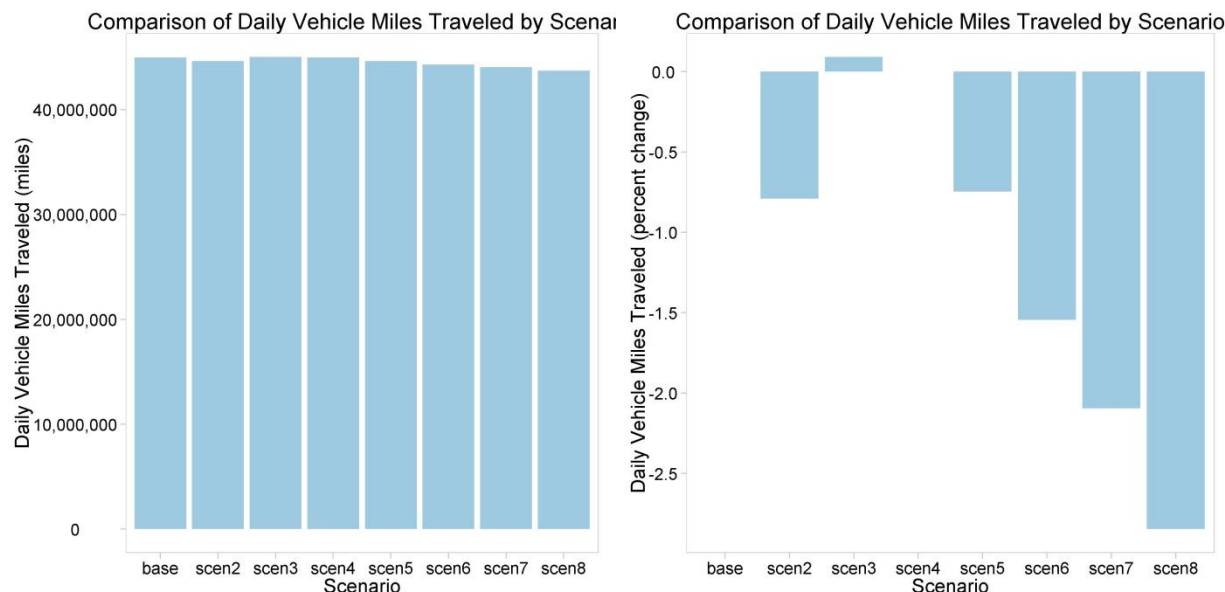
examples of different visualizations produced during the pilot tests that show the range of charts that can be produced. The settings for the report tabs are included for each chart.

### *Aggregate comparisons across scenarios*

Figure 7-3 show two charts from the Portland test of SmartGAP. The chart on the left shows total daily vehicle miles traveled (VMT) by scenario. In this case, eight scenarios were compared. While displaying the totals using the number measure provides an indication for each scenario of the total magnitude of VMT, the differences between the scenarios are difficult to interpret as they are relatively small in percentage terms leading to very similar bar heights in the chart. The chart on the right shows the output for the same scenarios and performance metric, but the measure is changed to the Index (0) type, which first scales the values to an index, with the base scenario set to 100, and then translates all of the index values to be relative to a base scenario value of 0. In effect, the values displayed are percent changes relative to the base scenario, with positive bars (just scenario #3 in this case) indicating an increase in VMT relative to the base scenario, zero bars (scenario #4 as well as the base) indicating the same VMT as the base scenario, and negative bars indicating a decrease in VMT relative to the base scenario.

The reports tab settings to produce the left and right charts respectively are as follows:

- |                |                                |                                |
|----------------|--------------------------------|--------------------------------|
| • Scenarios:   | Select base and scenarios #2-8 | Select base and scenarios #2-8 |
| • Metric:      | Daily vehicle miles traveled   | Daily vehicle miles traveled   |
| • Aggregation: | All                            | All                            |
| • Measure:     | Number                         | Index (0)                      |



*Figure 7-3: Portland Daily VMT by Scenario (Total and Percent Change from Base)*

### Segmentation within scenarios

Many of the performance metrics available on the reports tab can be segmented using the different aggregations other than all. SmartGAP only makes those available to the user that the data supports; once the user selects a performance measure, the aggregation levels that can be used will be selectable, with the remaining aggregations inactive and grayed out. A typical analysis using segmentation is to understand how the metric is distributed across the segments. Figure 7-4 shows an example from the TRPC pilot, where the charts show the distribution of population and employment by the development type aggregation. In this case, the measure is percentage and so the bars indicate the percentage of the population and jobs that are allocation to each development type. The bars sum to 100% across all of the development types.

The reports tab settings to produce the left and right charts respectively are as follows:

- |                |                       |                       |
|----------------|-----------------------|-----------------------|
| • Scenarios:   | Select base scenarios | Select base scenarios |
| • Metric:      | Population            | Employment            |
| • Aggregation: | Development type      | Development type      |
| • Measure:     | Percentage            | Percentage            |

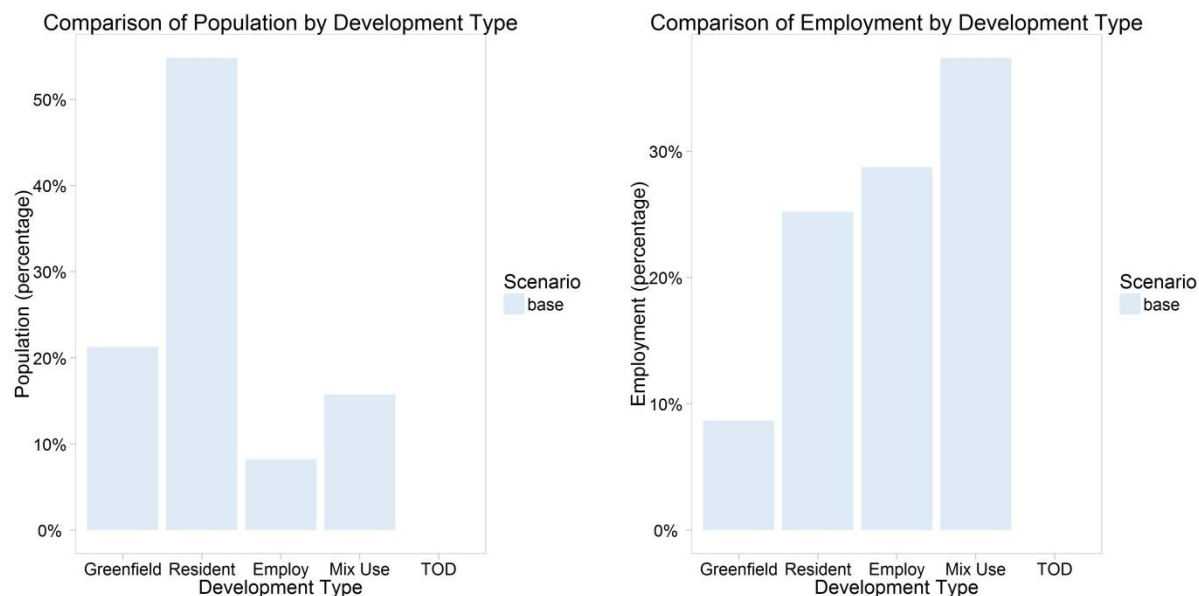


Figure 7-4: TRPC Percent of 2040 Population and Employment by Development Type

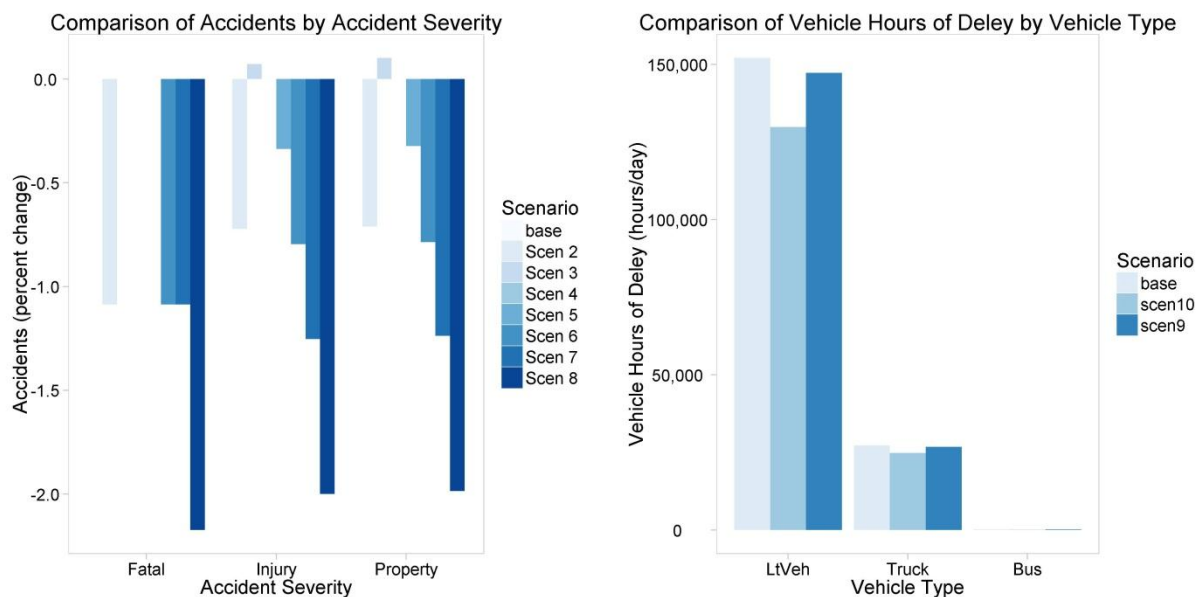
### Segmented comparisons across scenarios

The final type of comparison that can be achieved using the reporting tab is displaying a segmented performance metric across a series of scenarios. This allows comparison of say how the distribution of a performance metric is affected by different scenarios.

Figure 7-5 shows two examples of this type of chart. On the left, the accidents metric from eight scenarios is displayed segmented by accident severity, a three category segmentation with levels of fatal, injury and property. On the right, the vehicle hours of delay metric from three scenarios is displayed segmented by vehicle, another three category segmentation, this time with levels of light vehicle, truck, and bus. In this type of chart, the segmentation variable is the x-axis and the various scenario values are shown clustered for each segment. The difference between the two charts is the measure used. On the left, the measure is Index (0) and so the bars indicate relative percent change in comparison to the base scenario value for that segment (which has a value of zero and so no bar is shown). On the right, the measure is number and so the bars indicate the actual number of hours of delay experienced by each vehicle type in each scenario.

The reports tab settings to produce the left and right charts respectively are as follows:

- |                |                                |                                 |
|----------------|--------------------------------|---------------------------------|
| • Scenarios:   | Select base and scenarios #2-7 | Select base and scenarios #9-10 |
| • Metric:      | Accidents                      | Vehicle Hours of Delay          |
| • Aggregation: | Accident severity              | Vehicle Type                    |
| • Measure:     | Index (0)                      | Number                          |



*Figure 7-5: Accidents by Accident Severity (MDOT) and Vehicle Hours of Delay by Vehicle Type (Portland)*

## REFERENCES

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